G. S. C. Memoir 242 CYPRESS LAKE MAP-AREA, SASK. G. M. Furnival

CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA

MEMOIR 242

CYPRESS LAKE MAP-AREA, SASKATCHEWAN

BY

G. M. Furnival

OTTAWA
EDMOND CLOUTIER, C.M.G., B.A., L.Ph.,
KING'S PRINTER AND CONTROLLER OF STATIONERY
1950

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View of Ravenscrag Butte, exposing section of Whitemud, Battle, Frenchman, and Ravenscrag beds.

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PREFACE

This report deals specifically with the stratigraphy, structure, and economic resources of an area of some 3,100 square miles in the extreme southwest corner of Saskatchewan. Solution of the many problems encountered has, however, required the author to make an extensive survey of the available published information on neighbouring parts of the southwestern Plains on both sides of the International Boundary, and to supplement this, where necessary, with examinations on the ground. As a result, considerably more light has been thrown on the succession and possible extent of the subsurface formations beneath the Cypress Lake area, and more precise boundaries have been set to the various exposed formations. In particular, the Bearpaw formation of this region has been closely defined, and certain of its sandstone members have been found to provide critical data on the subsurface structure of the map-area and, in consequence, have afforded suggestive indications of the more favourable places in which to prospect for oil and natural gas. Studies of the succeeding Upper Cretaceous and Tertiary measures have led to some revision of existing nomenclature, and to the introduction of two new formational names. Further interesting information has, likewise, been added that may modify previous concepts of the origin of the Cypress Hills, and additional data have been collected on the numerous sandstone dykes in the Bearpaw beds.

The field work on which the report is based was done mainly in 1940 and 1941, when the author was in the employ of the Geological Survey, but has been supplemented in more recent years, as opportunity permitted, when re-examining this and adjacent regions as geologist for the Standard Oil Company of California. The present edition is essentially a reprint of the first, published in 1946 and now exhausted. As the author is no longer on the staff of the Geological Survey no attempt has been made to revise the original text, but a few recognizable errors have been corrected.

GEORGE HANSON,
Chief Geologist, Geological Survey of Canada

OTTAWA, March 1, 1950

Cypress Lake Map-Area, Saskatchewan

CHAPTER I

INTRODUCTION

THE AREA

Cypress Lake map-area comprises 3,100 square miles in Saskatchewan between longitudes 109 and 110 degrees west and latitudes 49 and 50 degrees north. It lies immediately north of the International Boundary and east of the Alberta boundary, and straddles the central part of the Cypress Hills. Maple Creek, on the main line of the Canadian Pacific Railway, is the principal town.

PREVIOUS GEOLOGICAL WORK

The map-area has been subject to repeated earlier geological investigations. G. M. Dawson (1875)[1] mapped and reported on the country in the immediate vicinity of the 49th parallel. R. G. McConnell (1885) geologically mapped a large area in southern Saskatchewan including Cypress Lake map-area. N. B. Davis (1918) made a detailed study of the Whitemud formation in the vicinity of Ravenscrag and Eastend during the 1916 field season. From 1923 to 1926 the southern part of Alberta and that part of Saskatchewan lying west of longitude 109 degrees was mapped by M. Y. Williams, W. S. Dyer, and E. J. Whittaker. Their results are incorporated in the Calgary sheet, Map 204A (1928) and in Memoir 163 (1930) by the Geological Survey. The southern part of Saskatchewan lying east of longitude 109 degrees was investigated and mapped during the years 1927 to 1931 by F. H. McLearn, L. S. Russell, P. S. Warren, and R. T. D. Wickenden. The results of this work are embodied in the Regina sheet, Map 267A (1935) and Memoir 176 (1935) by the Geological Survey. From 1931 to 1937 L. S. Russell, assisted by R. W. Landes, investigated and remapped the area in Alberta lying immediately west of the Cypress Lake sheet, and extending from 110 to 113 degrees west longitude. Their results are incorporated in Geological Survey Memoir 221 (1940).

PRESENT WORK

Though the Cypress Lake area had been investigated on several occasions, as indicated above, the geological structure of the Cypress Hills was still imperfectly known, and problems of stratigraphy and correlation that could only be determined by more detailed work required additional study. The writer remapped the area during the field seasons of 1940 and 1941, and the present report is based upon field studies during that period. The prime objective was to determine the oil and gas possibilities of the area. To achieve this two courses of investigation were pursued: first, the determination of the geological structure, so far as was possible from the limited data available from outcrops and deep-well logs; and, second, the study of the stratigraphic succession and

[1] Date of publication, as listed in Bibliography.

the correlation of beds with those of the recently mapped area in Saskatchewan east of the Cypress Lake map-area (Fraser *et al.*, 1935) and also with those in the still more recently mapped areas in Alberta immediately west of the map-area (Russell and Landes, 1940). The subsurface geology in contiguous areas is discussed briefly in an effort to provide some indication of possible subsurface conditions within the map-area. In this respect, particular attention is paid to the subsurface geology of north-central Montana and southern Alberta, where oil fields are being developed.

The methods used in recording and compiling the geological data of the area may be briefly outlined. All outcrops were sectioned carefully, and the position and elevation of each section were determined, for 90 per cent of the outcrops, by telescopic alidade and plane-table. The elevations of a number of isolated outcrops that otherwise would have required long traverses by plane-table were determined by altimeter. Care was exercised to eliminate, so far as possible, errors due to recent slumping of beds. For this purpose it was found advisable to carry elevations on many local, minor horizons in addition to the more important marker horizons and contacts. The sections measured in the field were plotted to scale, both horizontal and vertical, on profile paper, to aid in making correlations and determining structure. From these profiles it was possible to determine the vertical intervals from the many local horizons recorded in the field to the single stratigraphic horizon that was considered eventually most suitable as a structural datum. Convergences for various parts of the map-area became easily discernible, and many features that otherwise might have escaped detection were readily apparent. After the elevations for the structural datum were determined at every outcrop for which it could be calculated, these elevations were plotted in plan, and a structure-contour map prepared (*See* Map No. 856A, in pocket).

Large collections of fossils were obtained from widespread localities in the area. However, due to the lack of short ranging species, these proved of little assistance in making correlations.

It was not found possible to prepare isopach maps for the older formations underlying the area. Complete sections were lacking for those that outcrop, and only two deep wells for which reliable information is available have been drilled in the area, so that only general convergence directions may be determined for the deeply buried beds. These are indicated in the text.

OUTCROP INFORMATION

Outcrops, though limited in distribution, are in general more numerous within the map-area than is usual for the Plains, due to the presence of the dissected, easterly trending Cypress Hills, along the slopes of which are nearly 75 per cent of the rock exposures. Most of these occur along the valleys of the deeply entrenched streams flowing south or southeast from the hills, and in the vicinity of Cypress Lake. Outcrops are much scarcer on the northern slopes of the hills, and are mainly of hard, ledge-forming beds. There appears to be three reasons for this: (1) glacial deposits are thicker on these slopes due to unloading by southeastward moving glaciers as their gradients decreased on approaching the Cypress Hills; (2) post-glacial lake deposits are extensive north of the hills, due to the damming of glacial runoff as the glaciers receded; and (3) streams on the north slopes of the hills commence abruptly at the northern edge of the plateau-like summits, and have not retrenched southward into the hills for any appreciable distance. The contrast with the valleys on the south slopes is marked. North of the hills, the only outcrops, aside from a few isolated small exposures, are along Boxelder, McCoy, McShane, and Bear Creeks. South of the hills outcrops are plentiful along the south and west sides of Old

Man On His Back Plateau, along Coteau Creek in the vicinity of Boundary Plateau, and along Woodpile and North Fork Creeks. A few scattered outcrops were observed along Thelma Creek and upper parts of Battle Creek. The distribution of outcrops is shown on Map 856A (in pocket).

ACKNOWLEDGMENTS

The writer was ably assisted in the field during 1940 by Messrs. R. A. C. Brown, Wilfred Baillie, and Stewart Keddy, and in 1941 by Messrs. H. R. Robinson, F. J. Hamilton, and T. F. Connick. The plane-table work was done by W. Baillie, S. Keddy, and F. J. Hamilton.

Appreciation is here expressed for much helpful advice and guidance throughout the investigation from F. H. McLearn and R. T. D. Wickenden of the Geological Survey staff. McLearn is responsible for the study and identification of the many marine, Cretaceous invertebrate fossils collected from the area. Thanks are also due to Messrs. Douglas and H. R. Robinson who carried on independent studies of specimens of *Inoceramus* and *Baculites*, respectively, under the direction of McLearn. To C. M. Sternberg of the Geological Survey, who identified vertebrate remains from the Frenchman formation, and to Dr. L. S. Russell of the University of Toronto, who identified mammal teeth and freshwater fossils from the Cypress Hills formation, the writer expresses his thanks. Thanks are also due to R. T. D. Wickenden for his studies of the foraminifera in selected specimens of the Bearpaw marine shale.

Many kindnesses and courtesies were extended the writer and members of his party during the course of the field work, by the ranchers, farmers, and townsfolk of the area, and were much appreciated. He acknowledges, particularly, the hospitality of those ranchers who granted camping facilities, namely Messrs. Wylie, W. C. Caton, Harold Windsor, Walter Boyd, and R. E. Hansen. Acknowledgment is also made for camping privileges and general assistance extended by the staff of the Cypress Hills Forest Reserve, particularly by Mr. J. C. Colquhoun, the superintendent. Much useful information and assistance was provided by Mr. Fred Humphreys and engineering staff operating in the area under the Prairie Farm Rehabilitation Act.

PHYSICAL FEATURES

The dominating physical feature of the area is the nearly flat-topped, dissected, Cypress Hills Plateau. It covers an area 100 miles long, in an east-west direction, and 15 to 20 miles broad. The hills completely cross the map-area and extend 35 miles to the west and 20 miles to the east beyond its boundaries. Flanked on the north and south by low, rolling plains, they occupy 30 per cent of the map-area. They rise to an elevation of 3,850 feet on the east side of the area and 4,600 feet on the west side, in contrast with elevations as low as 2,400 feet in the northern part of the map-area and 2,800 feet at the International Boundary. The hills constitute a part of the Continental Divide between waters that flow south via Missouri River to the Gulf of Mexico and those that drain north to the South Saskatchewan and thence to Hudson Bay. However, most of the northward-flowing creeks within the map-area comprise part of an interior drainage system that supplies a group of alkaline lakes lying north of the map-area. The southern slopes of the hills are much more deeply incised than the northern, and the creeks have entrenched themselves to within a few miles of the northern edge of the hills, indicating that a more mature drainage system has developed on the south slopes. The presence of obsequent tributaries to Frenchman River, such as Conglomerate and Farewell Creeks, is indicative of an interrupted development of the drainage system south of the hills.

Most of the creeks on the southern slopes flow into the east-west drainage channel consisting of Frenchman River and Cypress Lake with its headwaters on Oxarart Creek. West of Oxarart Creek the drainage is south and south-eastward along Battle and Thelma Creeks to Milk River, and thence to the Missouri.

A prominent topographic feature of the hills is "The Gap", a broad shallow valley some 4 to 6 miles across and 300 feet deep, extending northerly across the hills in ranges 27 and 28, townships 7 and 8. Glacial moraines and kettle-hole lakes occur in "The Gap" and it appears to be largely of glacial origin.

Williams and Dyer (1931, pp. 109-110) have discussed the drainage system and attendant topographic features south of the hills very adequately as follows:

"Frenchman River heads in small glacial lakes drained by Oxarart creek, but its main source is Cypress lake....... The impounding of the water in Cypress lake is due to the silting up of the lower part of Oxarart creek, through which the lake drained into Battle creek, and by the raising of its eastward drainage channel by the inwash of large quantities of sediment by the waters of Sucker, Belanger, and Davis creeks, which descend by steep slopes from Cypress hills to the north.

"Below Cypress lake, the valley of the Frenchman compares in many respects with Milk River gorge. It is canyon-like, about ¾ mile in average width at the bottom, and is 500 feet deep in many places. Its bottom is deeply buried by clay, silt, and sand over which the river meanders as far as Palisade coulée, 10 miles below Cypress lake. Below this, the river has excavated a channel through the Pleistocene deposits as far as East End. Three miles below Ravenscrag the remains of the silt filling extend up the banks of the river 350 feet above the river level. The present gradient of the river from the lake to Ravenscrag is about 7 feet a mile and from Ravenscrag to East End about 10 feet a mile.

"From the north, many intricate deep valleys enter the main valley, those below Palisade coulée being in obsequent arrangement........

"On the south a still more remarkable valley opens into Frenchman gorge north of Palisade station. It contains no stream, but is followed by the Weyburn-Manyberries branch of the Canadian Pacific Railway. The floor of this coulée is almost level and opens to the south into an old shallow channel with southwest direction and slope. For convenience this ancient valley may be called Palisade coulée.

"......There are......special characteristics of the Frenchman system which need explanation, the most important being the east-west trend of the river from Cypress lake to East End, rather than down the slope to the south; and the apparent reversal of drainage between Palisade coulée and East End as indicated by recent down-cutting in Pleistocene silt, by obsequent tributaries which do not enter the river at grade, and by the ancient channel to the south, spoken of as Palisade coulée.

"Moraines, kettles, boulders, and a general glaciated topography characterize the upland south of Ravenscrag and East End, indicating that an extensive ice lobe, diverted south by the elevation of Cypress hills, covered this region extending in a southwest direction. Through The Gap, another ice lobe evidently extended southeast at least as far as Cypress lake and perhaps farther. The first course taken by the runoff of these two lobes appears to have been between them through Palisade valley, and out onto the south-sloping plain in a wide, shallow depression, now followed by the railway, to the valley of Battle creek at Vidora. Under these conditions the flow from Cypress lake was as at present, but the flow from the northeast and west of East End was opposite that of today. As the "Gap" lobe retreated, part of the runoff found its way into Battle creek west of Cypress lake, which in its flooded condition probably flowed in part down Battle creek, although still maintaining its main easterly flow. As the ice retreated still farther and the flow of water slackened, huge deposits of silt and sand were swept into the stream valleys and out onto the southern plain where they are still to be seen. With the final retreat of the easterly ice lobe, the channel of the Frenchman below East End was developed, and due to its favourable grade, it gradually extended its course headward through the alluvial filling of the valley west of East End, until by the capture of stream after stream the Palisade gap was reached and the headwaters of the modern Frenchman river were turned from their southerly course into their present direction of flow."

Two noteworthy topographic features, in addition to those already described, are Old Man On His Back Plateau and Boundary Plateau. The former is bounded on the southwest by a sharp, flat-topped escarpment about 6 miles long, in township 3, ranges 24 and 25, rising to an elevation of more than 3,500 feet and some 300 to 400 feet above the plains to the south. Its north and northeastern

extensions, in townships 3 and 4, ranges 23, 24, and part of 25, are obscured by an area of glacial moraines and drumlins. Eastwards the escarpment drops gradually to prairie level. Southeast of this plateau, across a broad valley, is the gently undulating Boundary Plateau, only the western part of which extends into the map-area. This plateau likewise rises several hundred feet above the surrounding prairie surface to an elevation of about 3,500 feet. It appears to be the northern extension of the Cherry Ridge of Montana.

GENERAL GEOLOGY

Geologically, the Cypress Hills map-area lies at about the centre of a triangular area, bounded on the east and northeast by the northwest trending Moose Jaw-Williston sedimentary and structural basin, on the west by the broad uplifted area of central Alberta known generally as the Sweetgrass arch, and on the south by the east-west trending sedimentary basin of east-central Montana. Within this triangular area relatively few deep wells have been drilled, and surface exposures, far from adequate, are localized in their distribution, so that positive information regarding general geological relationships to these broader features is limited.

The Cypress Lake map-area is underlain by sediments of Upper Cretaceous and Tertiary age. The oldest formation exposed is the Lea Park, and the youngest is the Cypress Hills formation of Tertiary age. The complete sequence is shown in the following table of formations:

TABLE OF FORMATIONS

Period	Epoch	Formation	Thickness Feet	Lithology
Quarternary	Pleistocene			Boulder clay, lake silt, sand, etc.
Erosional unconformity				
Tertiary	Oligocene	Cypress Hills	50—550+	Conglomerate, sandstone, marl, clay, etc. Continental deposits.
	Erosional unconformity			
	Paleocene	Ravenscrag	227+	Buff and grey sand, silt and clay, lignite, etc. Non-marine.
Cretaceous	Upper Cretaceous	Frenchman	10—150+	Sandstone; *Triceratops* fauna. Non-marine.
		Erosional unconformity		
		Battle	20—30	Bentonitic shale, silt, sand. Non-marine.
		Whitemud	33—45	White to grey clay; sandstone; silt. Non-marine.
		Eastend	70—120	Sand, silt, clay; lignite. Marine to non-marine.
		Bearpaw	940—1,000	Dark marine shale; Belanger and Oxarart sandstone members.
		Oldman and Foremost	585—820	Sandstone, shale, and lignite, sandstone predominating. Non-marine. Sandstone, shale, and lignite, shale more abundant. Interbedded marine and non-marine.
		Lea Park: Pakowki	500—560	Dark grey marine shale.
		Lea Park: Milk River	300—310	Chiefly shale; sandstone; sandy shale; chert pebbles.

TABLE OF FORMATIONS—*Concluded*

Period	Epoch	Formation	Thickness Feet	Lithology
Cretaceous	Upper Cretaceous	*Formations penetrated by deep wells but not exposed*		
		Alberta	1,100—1,400	Dark grey marine shale.
	Lower Cretaceous	Marine	300—330	Dark grey shale; sandstone.
		Non-marine	110—200	Drak grey, red, and green shale; lignite; salt and pepper sandstone.
Erosional unconformity				
Jurassic			380—520	Shale; limestone, dense; sandstone.
Erosional unconformity				
Mississippian		"Big Snowy group"	?	Limestone, sandstone, shale.
	Madison	"Mission Canyon"	?	Limestone, crystalline, light coloured.
		"Lodgepole"	?	Limestone, dark, argillaceous; sandstone; shale.
Devonian or Mississippian		Exshaw	10—50	Shale, black, non-calcareous.
Devonian		"Three Forks"	?	Shale, green; dolomite.
		"Potlach"	?	Anhydrite.
		"Jefferson"	?	Dolomite, crystalline; anhydrite.

The Bearpaw formation is the most widespread, underlying 60 per cent of the map-area to the north and south of the Cypress Hills. The Tertiary formations are restricted largely in their distribution to the higher parts of the Cypress Hills. The total thickness of the stratigraphic section represented by the exposed formations does not exceed 1,850 feet for the Cretaceous and 800 feet for the Tertiary formations or a total of 2,650 feet. Two unconformities, one at the base of the Frenchman formation and the other at the base of the Cypress Hills formation, interrupt the otherwise conformable sequence of strata. The sediments lying above the Bearpaw shales and below the Cypress Hills conglomerates and sandstones are in general poorly consolidated, and should be referred to as sands, silts, and clays rather than as sandstones and shales, although hard beds do occur in the Whitemud and Frenchman formations. The sandstones and conglomerates of the Cypress Hills formation are firmly cemented, and commonly form rocky ledges.

Only on Woodpile and Bear Creeks have the strata been deformed to the extent that they dip at angles of 20 degrees or more; elsewhere the beds have dips measurable in feet per mile rather than in degrees.

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CHAPTER II

PALÆOZOIC STRATIGRAPHY

INTRODUCTION

The Palæozoic formations underlying the Plains of southeastern Alberta and southwestern Saskatchewan are known only from deep-well samples. Less than a dozen deep wells have been drilled in this region, and of these only two penetrated far into Palæozoic rocks. Only limited information is, therefore, available regarding the stratigraphy of the Palæozoic beds underlying the map-area.

PRE-DEVONIAN

General information from contiguous areas indicates that shales, arkoses, limestones, and sandstones of Cambrian age, and dolomitic limestones of Cambrian or Ordovician age, having an aggregate thickness between 500 and 1,000 feet, are present in southern Alberta (Hume, 1944, p. 21). Reeves (1924, p. 75) found 800 feet of Cambrian beds in the Little Rocky Mountains, Montana, 70 miles south of the Cypress Lake map-area. Dolomitic limestone of Ordovician age has been identified in the Bearpaw Mountains, Montana, 40 miles south of the map-area (Reeves, 1924, p. 71). Beds of Cambrian and possibly also Ordovician age may extend into the Cypress Lake area, but no Silurian beds have been recognized in this part of the Plains.

DEVONIAN

The Devonian strata of north-central Montana have been subdivided into three chief lithologic units. Peale (Peale and Merrill, 1893, p. 27) applied the name "Jefferson" to dolomitic limestone and dolomites of Devonian age comprising the lowermost division, some 640 feet thick. Perry (1928) first used the name "Potlach" for 940 feet of Devonian beds penetrated by the Potlach-Adams No. 1 well in the Kevin-Sunburst field of Montana. These beds consist of some 500 to 600 feet of dolomitic limestone and dolomite at the bottom overlain by 250 to 300 feet of anhydrite, then by about 50 feet of green, calcareous, splintery shale and buff to grey, dolomitic limestone containing Upper Devonian fossils. The uppermost beds have subsequently been referred to the "Three Forks" formation by Roy Lebkicker and Romine (Romine, 1929, and P. D. Moore, 1931, pp. 1149-1152) using the term first applied by Peale (Peale and Merrill, 1893) to calcareous shales overlying the Jefferson in the Three Forks area of Montana. The lower 500 to 600 feet of dolomitic limestone and dolomite Lebkicker and Romine (Romine, 1929) correlate with the Jefferson, leaving the term Potlach restricted to the intermediate anhydrite member, to which they assign a Three Forks age, tentatively.

Moore (1931) shows that there is a threefold lithologic subdivision of the Devonian in the southern Alberta Plains. The Devonian penetrated by the Hudson's Bay Oil and Gas Eyremore No. 1 well, in sec. 26, tp. 17, rge. 18, W. 4th mer., consists in descending order of 30 feet of grey to buff limestone followed by 290 feet of chiefly anhydrite, then by buff dolomite and dolomitic limestone for 470 feet to the bottom of the well (Hume, 1933, p. 187).

A number of other wells drilled in the southern Alberta Plains, and for which logs have been published, demonstrate the widespread distribution of the three lithologic units, though they differ somewhat in thickness from place to place. These wells are as follows: the Commonwealth Milk River No. 1, sec. 9, tp. 3, rge. 15, W. 4th mer. (Hume, 1933, p. 154; Moore, 1931); Northwest Bow Island Burdette No. 1, sec. 8, tp. 11, rge. 11, W. 4th mer. (Hume, 1933, p. 148; Moore, 1931), some 50 miles west of the Cypress Lake map-area; Roth and Faurot No. 1 well, sec. 6, tp. 13, rge. 5, W. 4th mer., near Medicine Hat, only 30 miles west of the Cypress Lake map-area (Hume, 1933, p. 152); and Northwest Erickson Coulée No. 1, sec. 8, tp. 1, rge. 12, W. 4th mer. (Hume, 1933, p. 156; Moore, 1931). A number of additional wells drilled subsequent to these, and for which detailed logs have not yet been published, further confirm the threefold subdivision of the Devonian throughout southern Alberta. Porous zones are present in the upper part of the lowermost subdivision.

No wells in Saskatchewan within 100 miles of the map-area have penetrated as deep in the stratigraphic section. Micro-fossils of Devonian age have been found in red beds associated with anhydrite and dolomitic limestones in the Simpson No. 1 well, 190 miles northeast of the map-area, and in the Pike Lake well, 175 miles north-northeast (Wickenden, 1932). It seems probable, however, in view of the widespread distribution and uniform character of these lithologic units throughout southern Alberta, that they will be found to underlie the Cypress Lake map-area without much change in character.

DEVONIAN OR MISSISSIPPIAN

In southern Alberta Upper Devonian strata are overlain by a widespread bed of non-calcareous, black, fissile, lean bituminous shale that rarely exceeds 20 feet in thickness. In Montana the shale was formerly included with the Three Forks formation (Romine, 1929; Moore, 1931). In Alberta it has been generally correlated with the Exshaw formation lying at the top of the Devonian, Minnewanka limestone near Exshaw, Alberta, where it contains Devonian fossils (Warren, 1937). However, a recent study of the conodonts (worm jaws) in the shale of southern Alberta and Montana, by C. L. Cooper and L. L. Sloss (1943), show these to be of Mississippian, Kinderhook age. The authors point out that the formation should, therefore, be correlated with the basal Lodgepole shale of Montana rather than with the Exshaw of the Rocky Mountains, and that it should be considered as the basal unit of the Lower Mississippian, Madison group. Supporting this view is the presence at many places of a sharp break between the shale and the underlying calcareous shale of the Three Forks, whereas the black shale at its upper surface is intercalated with beds of Mississippian age. C. O. Hage (1943) finds evidence of an unconformity at the base of the Exshaw shale in the Dyson Creek area west of Turner Valley, Alberta.

The Roth and Faurot No. 1 well near Medicine Hat drilled from 10 to 20 feet of black, fissile, non-calcareous shale between depths of 3,670 and 3,690 feet at the base of the Mississippian strata. In the Northwest Bow Island Burdette No. 1 well at Bow Island, Alberta, black, non-calcareous shale at the base of the Mississippian was probably not more than 10 feet thick.

As in the case of the overlying Mississippian and the underlying Devonian formations, this black, non-calcareous, fissile shale is known from deep wells to have a wide areal extent not only throughout southern Alberta and north-central Montana but eastward into northwestern North Dakota (O. A. Seager *et al.*, 1942, p. 1421) and southwestern Montana, where it reaches a thickness of more

than 100 feet. There seems little doubt, therefore, that it will underlie the Cypress Lake map-area. The shale not only provides an excellent marker horizon but serves as a splendid datum for subsurface structural and stratigraphic studies.

EARLY MISSISSIPPIAN

The Mississippian strata underlying the northwestern Plains outcrop in the numerous mountain outliers in central and north-central Montana. Here they have been subdivided into the Big Snowy group of Middle to Upper Mississippian age (Scott, 1935; Perry and Sloss, 1943) and an underlying Madison group of Kinderhook to Osage age (Peale, 1893; L. L. Sloss and R. H. Hamblin, 1942).

The Madison group has been divided into the Mission Canyon and underlying Lodgepole formations (A. J. Collier and S. H. Cathcart, 1922; Sloss and Hamblin, 1942). The Lodgepole consists chiefly of dark-coloured, fine-grained, dense limestone with interbedded calcareous shale and argillaceous limestone, some 300 to 600 feet thick. The overlying Mission Canyon, 400 to 700 feet thick, is made up of uniformly bedded, massive, generally light coloured to brown limestone, cherty at places. Preliminary study of the fauna indicates a Kinderhook and Osage age for the Madison group (Sloss and Hamblin, 1942, p. 311).

The twofold subdivision of the Madison group is recognized in the Kevin-Sunburst field where the truncated Mission Canyon beds are directly overlain by Jurassic strata (Sloss and Hamblin, 1942). Moore (1931, p. 1145) recognizes a similar twofold subdivison of the limestone strata lying above the black, non-calcareous, fissile "Exshaw" shale and below the Jurassic and Cretaceous beds of the southern Alberta Plains. He points out that the upper division consists chiefly of massive, white, some pink, crystalline limestone, with dolomitic and cherty zones. At places abundant fossils, consisting in large part of crinoid ossicles and fenestellid bryozoans, are present. In contrast, the lower division is fine-grained, dense, darker coloured, generally thin-bedded limestone and shaly limestone. Hume (1933, pp. 48, 49) shows that in Alberta the two divisions can be traced from the wells near the International Boundary, such as the Commonwealth Milk River No. 1, sec. 9, tp. 3, rge. 15, W. 4th mer., where the upper division of light-coloured limestone is 820 feet thick and the lower dark-coloured, argillaceous limestone division is 280 feet thick, some 85 miles north to the Hudson's Bay Gas and Oil Eyremore No. 1, sec. 26, tp. 17, rge. 18, W. 4th mer., where the divisions are 530 and 220 feet thick respectively. The twofold subdivision has been traced eastward to the Northwest Bow Island Burdette No. 1 well at Bow Island, Alberta, to the Roth and Faurot No. 1 well at Medicine Hat, 30 miles west of the Cypress Lake map-area, and to the Drazan No. 1 well at Many Islands Lake, only some 15 miles northwest of the map-area. Red and pink limestone beds are prominent in the upper zone in these latter wells.

Moore and Hume both note the thinning of the upper division of light-coloured limestone from south to north and from west to east. This they point out is due chiefly to northeastward bevelling of the Mississippian strata by post-Palæozoic erosion prior to deposition of Mesozoic sediments.

Dolomitized and cherty porous zones are present at the top, an old erosion surface, of the Mississippian limestone at many places in southern Alberta. Other porous zones are known to occur in lower beds. Quartzose sandstone interbedded with limestone at the base of the lower limestone division, immediately above the "Exshaw" shale, extends as much as 80 feet above it (Hume, 1933, p. 156; Moore, 1931, pp. 1145-6). Subsequent drilling has shown this sandstone to be widespread throughout the Plains and to be porous.

Though palæontologic evidence is not yet available to determine the exact age of the beds penetrated by the wells in southern Alberta, correlation of the

two divisions recognized here with the two divisions established for the Madison in the Kevin-Sunburst field has been suggested (Russell and Landes, 1940, p. 12) largely on the bases of lithology, relations to adjacent strata, and continuity throughout the wells cited above. Additional wells drilled in the southern Alberta Plains subsequent to those whose logs have been published support this view.

Eagle Butte No. 2 well, at the western end of the Cypress Hills, 17 miles west of the map-area, in sec. 30, tp. 7, rge. 3, W. 4th mer., penetrated some 80 feet into white limestone, chert, and a little green shale and sandstone, at the base of Jurassic beds, that may represent the weathered surface of the upper division of the Mississippian or very close to it. This is at an elevation of 746 feet below sea-level.

At drilling depths of 3,665 to 3,677 feet the Twin Province No. 1 well, in sec. 21, tp. 11, rge. 29, in the northwest corner of the map-area, penetrated 12 feet of interbedded limestone, sandstone, and grass-green shale with much secondary silica, which is believed to represent the weathered surface of a pre-Jurassic limestone (*See* log of well in Appendix). This may be the top of the Mission Canyon equivalent or the surface of a limestone member of the younger "Big Snowy" group.

The Northwest Boundary No. 1 well, at the south border of the map-area, in l.s. 4, sec. 9, tp. 1, rge. 27, entered limestone at a depth of 3,940 feet and bottomed in it at 3,960 feet. Though it has been designated as Palæozoic limestone (Williams and Dyer, 1930) it has not been identified positively as such. The section from the top of the Jurassic down to the limestone in this well is only 200 feet thick, as compared with 526 feet in the Signal Butte No. 1 well, in sec. 19, tp. 37N-15E, Montana, about 10 miles southwest of the Northwest Boundary No. 1 well. It seems possible, therefore, that the limestone at the bottom of the latter well may be younger than Mississippian.

The Signal Butte No. 1 well, referred to above, penetrated chert and cherty limestone from 4,278 to 4,300 feet, the bottom of the well. This appears to represent the weathered surface of the Mission Canyon formation, but could also be a younger Mississippian limestone of the Big Snowy group.

The thicknesses of the Mission Canyon and Lodgepole equivalents in Saskatchewan wells north and east of the map-area are not known. In any case these wells are at some considerable distance from the area mapped. The Mission Canyon equivalent, which, like that in Alberta, may be bevelled to some extent by erosion within the Cypress Lake map-area and so be thinner than in extreme southern Alberta or in Montana, is estimated to be 250 to 350 feet thick here. However, as discussed subsequently, elements of the younger "Big Snowy" group may overlie the "Mission Canyon" within the map-area. Where this condition obtains, the erosion that bevelled the "Mission Canyon" of southern Alberta will not have affected these beds, and the "Mission Canyon" section in this case may be more analogous to that in the eastern Montana and North Dakota wells, where the thickness ranges from 400 to 700 feet. It seems unlikely, in either case, that the underlying equivalent of the Lodgepole has been affected by this erosion. This lower division is comparatively uniform in thickness and character across southern Alberta and northern Montana, and no doubt underlies the map-area with slight change in thickness and lithology. Its thickness is, consequently, estimated to range from 250 to 400 feet. The early Mississippian, Madison equivalent, therefore, may occupy a total of 500 to 1,100 feet of the Palæozoic stratigraphic section in the Cypress Lake map-area.

MIDDLE AND UPPER MISSISSIPPIAN

A series of shales, sandstones, limestones, and evaporites of Middle and Upper Mississippian age overlies the Madison limestone in eastern Montana, western North Dakota, and northwestern South Dakota. Though the basin in which these sediments lie has a general easterly trend, its northern limits may extend well north into Saskatchewan, at least as far as Regina. These sediments were first named the "Big Snowy" group by Scott (1935). He included in the group all beds that lie between the Madison limestone and the late Mississippian to early Pennsylvanian Amsden formation of south-central Montana. The type section is in the Big Snowy Mountains of Montana. There the Big Snowy group was divided by Scott into three formations, which, in descending order, are the Heath, Otter, and Kibbey, the last resting disconformably upon the Mission Canyon. More recently Seager (1942) applied the name Charles formation to a series of beds lying between the Kibbey formation and the top of the Mission Canyon limestone in eastern Montana. The Charles has never been observed in outcrop, being known only from deep-well cores and samples. Its type section is that encountered in drilling Arro-California Company Charles No. 4 well in sec. 21, tp. 15N, rge. 30E, Mosby dome, Montana.

The lithology, distribution, and correlation of the Big Snowy group have been discussed by Perry and Sloss (1943).

The Charles formation averages some 600 feet in thickness, and may vary within 30 miles from as much as 950 feet to nil, due to a restricted basin of sedimentation at this time. It consists chiefly of light-coloured, earthy limestones and dolomites interbedded with evaporites in beds as much as 100 feet thick. The evaporites are largely anhydrite with some salty, red and variegated shales. Sandy zones may be present near the top. The position of the lower contact is a matter of controversy, but is generally placed at the base of the lowest thick bed of anhydrite.

Overlying the Charles is the Kibbey formation, consisting of dull, brick-red, dolomitic, shaly sandstone with, locally, beds of gypsum. The lower contact is transitional into the underlying Charles. Where the Charles is absent, it rests disconformably on Mission Canyon limestone. The Otter overlies the Kibbey. It consists essentially of bright green shales with intercalated grey shale and fossiliferous, oolitic limestones totalling as much as 500 feet.

The topmost formation, the Heath, is chiefly black, fissile, conodont-bearing shales, grey shales, and massive, brownish sandstones. Some grey limestone is present. The sandstone beds range to 20 feet in thickness, and are composed of well-sorted clear quartz grains, poorly rounded, but showing some secondary growth. The greatest measured thickness of the Heath is 560 feet.

Perry and Sloss (1943) have prepared palæogeographic maps showing the approximate distribution of these formations. As previously mentioned, they have been found to extend northwards some distance into southern Saskatchewan, but available data are not sufficient to define the northern limits. Red and purple dolomite and anhydrite at the base of Jurassic beds in the Smith-G.-Sorenson Co., Smith No. 1 well, sec. 22, tp. 37N, rge. 7E, Montana, 4 miles south of the International Boundary and only some 30 miles west of the southwest corner of the map-area, have been referred to the Big Snowy group. However, it is not yet certain that these beds are not non-marine Jurassic. It would seem highly probable that elements of the Big Snowy group are present within the Cypress Lake map-area, but no estimate of their thicknesses or character can be ventured.

CHAPTER III

EARLY MESOZOIC STRATIGRAPHY

TRIASSIC

Beds of Triassic age have not been identified in this part of the central Plains region, but possibly underlie an extensive area to the east as far as the Manitoba escarpment. The marine Triassic of western Alberta thins rapidly eastward, and is not known in the southern Alberta plains. Apparently this region either lay above sea-level throughout Triassic time, or the deposits were subsequently eroded. Wickenden (1945, p. 8) states that farther east a series of red shale and gypsum beds 140 to 240 feet thick was penetrated by wells in the Neepawa-Dauphin district of Manitoba. These have been named the Amaranth formation. No diagnostic fossils were found, but according to Wickenden the beds are similar in lithology to beds of the Spearfish formation of Triassic age penetrated by the California Kamp well in North Dakota (Seager, 1942, p. 1418). The Speakfish formation is known to occur at widely separate points in Montana, and it seems probable that similar rocks of Triassic age may be present in parts of southern Saskatchewan, though doubtfully as far west as the Cypress Lake map-area.

JURASSIC

Jurassic sediments in the Alberta plains are known only from deep well samples. They are confined chiefly to the area south of Oldman River. From there, where total thicknesses are commonly less than 100 feet, they thicken southward into Montana and eastward into southern Saskatchewan.

The Jurassic formations lie unconformably on Palæozoic strata, and are separated by an unconformity from overlying Lower Cretaceous beds. Their aggregate thickness throughout the Plains, therefore, varies greatly. They are composed generally of dark grey to green, marine shales with variable amounts of limestone and sandstone. A basal sandstone is commonly present. Non-marine zones are known to occur in Montana and Manitoba.

The Jurassic is represented in southeastern Alberta and north-central Montana by the Ellis formation or its equivalents (Peale and Merrill, 1893, Peale, 1896; J. O. G. Sanderson, 1931). Near the International Boundary north of the Kevin-Sunburst field these beds are more than 250 feet thick, whereas north of Oldman River the Jurassic was eroded prior to deposition of Lower Cretaceous sediments. Where present, south of the Oldman, it consists chiefly of dark green to grey, hard, splintery, finely pyritic shale. Thin, calcareous shale or "lime" beds are common. A basal sandstone is present over a large part of the area. This is generally fine- to medium-grained, highly quartzose, commonly calcareous, light grey sandstone, commonly possessing excellent porosity and permeability. Glauconitic shale zones are present in the upper part of the formation. At places the beds pass upwards into finely laminated, very fine-grained sandstone and micaceous shale up to 90 feet thick that has been named the "Ribbon sandstone" (Blixt, 1941). A green mineral disseminated throughout the sandstone, though not yet positively identified, is believed to be glauconite. The sandstone has been correlated both with the "Cutbank sandstone" of Lower Cretaceous age (Blixt, 1941, pp. 362-364), and with the "Passage

Beds", the finely interbedded sandstone and shale that marks the transition from the Jurassic, Fernie strata to the Lower Cretaceous, Kootenay formation of the Blairmore-Crowsnest Pass area. At the McDougall Segur Comrey No. 1 well, sec. 9, tp. 1, rge. 5, W. 4th mer., about 28 miles west of the southwest corner of the map-area, some 90 feet of finely interbedded sandstone and shale in this zone lies between the top of the typically dark green "Ellis" shale and the base of the Lower Cretaceous sandstone.

Southeastward into Montana, where thicker sections of Ellis beds are known, interbedded limestone and sandstone are common near the base of the formation. The limestone is chiefly buff to dark grey and dense. It is distinguished from the Palæozoic limestones by its generally non-crystalline character. The detailed section of the Ellis in the Signal Butte No. 1 well, Montana, 3½ miles south of the map-area, is presented in the log of the well in the Appendix, between depths of 3,760 and 4,280 feet, and illustrates these characters. The descriptions were copied from a log prepared by G. L. Post'e for A. B. Cobb and Company and the Yale Oil Corporation of Montana. The section may be summarized briefly as follows:

Drilling depths	Description	Thickness
Feet		Feet
3,760–4,055	Shale, dark grey, interbedded with grey sandstone; *Gryphaea* and *Belemnites* 3,937 to 3,969 feet	295
4,055–4,089	Shale, dark grey, calcareous; and interbedded dark grey limestone	34
4,089–4,146	Sandstone, calcareous, porous, oil saturated; and interbedded white, dolomitic limestone	57
4,146–4,224	Limestone, buff to grey	78
4,224–4,267	Chiefly shale, dark grey	43
4,267–4,280	Conglomerate, bluish green shale matrix with fragments of limestone and chert	13
	Total thickness[1]	520

[1] Because of the nearly horizontal attitude of the strata penetrated by wells in this region drilling depths are accepted as measures of true thicknesses, unless otherwise indicated.

The top of the Jurassic section is at a depth of 3,760 feet, or at an elevation of 845 feet below sea-level. The base of the section is at a depth of 4,280 feet. R. T. D. Wickenden of the Geological Survey, Canada, examined a piece of the buff, dense limestone, cored at a depth of 4,220 feet, and identified Jurassic foraminifera in it. The beds below 4,280 feet may belong either to the Madison, as indicated by the Great Falls office of the United States Geological Survey, or they may belong to a member of the younger, "Big Snowy" group.

Within the Cypress Lake map-area the Jurassic beds have been penetrated by the Northwest Boundary No. 1 and the Twin Province No. 1 wells. The Northwest Boundary No. 1 well encountered the following section (Wickenden, 1932, p. 179):

Drilling depths	Description	Thickness
Feet		Feet
3,750–3,810	Shale, medium grey to dark grey; Jurassic foraminifera 20 feet below top	60
3,810–3,900	Shale, calcareous, light to dark grey; many Jurassic foraminifera to 3,880	90
3,900–3,920	Shale, dark grey, hard, fissile, slightly calcareous	20
3,920–3,930	Shale, grey, hard, fissile, highly calcareous	10
3,930–3,950	Samples missing; reported as limestone	20(?)
	Total thickness	180+

The top of the section is at a depth of 3,750 feet, or at an elevation of 974 feet below sea-level. Below 3,930 feet, to the bottom of the well, the rock is limestone and has been designated as Palæozoic in age (Williams and Dyer, 1930). There is, however, strong probability that the limestone is younger, for the Signal Butte No. 1 well, about 10 miles to the west-southwest, encountered 520 feet of Jurassic beds, and it seems reasonable to conclude that the limestone in the Northwest Boundary No. 1 well is also of Jurassic age.

The Twin Province No. 1 well, in the northwest corner of the map-area, according to Wickenden (*See* well log, Appendix) penetrated the following summarized section of Jurassic beds:

Drilling depths	Description	Thickness
Feet		Feet
3,290–3,370	Shale, medium to light grey; Jurassic foraminifera	80
3,370–3,490	Sandstone, grey; interbedded grey shale	120
3,490–3,585	Limestone, chiefly buff to brown, dense; oolitic at places	95
3,585 3,670	Shale, chiefly, calcareous, grey; Jurassic foraminifera to 3,620; interbedded limestone near bottom	85
3,670–3,677	Limestone; shale; breccia of pale green shale, chalcedony, and grey chert; grit	7
	Total thickness	387

This section extends from a depth of 3,290 feet to 3,670 feet, and the elevation of the top is 643 feet below sea-level. Wickenden has pointed out the abundance of chalcedonic quartz or chert in the lowest few feet of the section, and suggests that the Palæozoic limestone may not be far below the present bottom of the well. Whether this will be an equivalent of the Madison of Montana or the overlying Big Snowy group cannot be predicted.

The character of the Jurassic beds encountered in this well differs considerably from those generally found throughout the southern Alberta plains in that the shales are no longer predominantly green; massive limestone beds are present in the bottom part of the section; and the upper beds are more sandy. It is possible that the limestone beds below a depth of 4,146 feet in the Signal Butte No. 1 and below 3,490 feet in Twin Province No. 1 wells represent beds older and lower in the section than those commonly encountered in southern Alberta, and that the petroliferous sandstones from 4,089 to 4,146 feet in the Signal Butte No. 1 well may correlate with the petroliferous "Basal Ellis" sandstone of southern Alberta. These beds would then correlate with some part of the section between 3,370 and 3,490 feet at the Twin Province No. 1 well. Furthermore, on the basis of the two wells referred to above, it may be estimated that the Jurassic beds underlying the Cypress Lake map-area may average 400 to 500 feet in thickness.

The nearest well to have penetrated the Jurassic strata within the Cypress Hills proper is the Eagle Butte No. 2, drilled on the west side of Medicine Lodge Coulée, 17 miles west of the map-area. The following is the section of Jurassic encountered, according to Hume (1933, p. 166):

Description	Thickness Feet
Shale, greenish grey, calcareous	170
Shale and sandstone, greenish grey	10
Shale, greenish grey, with limestone	30
Shale, greenish grey, a little limestone	30
Limestone, light buff; grey shale	40
Shale, greenish grey	20
Limestone	10
Shale, greenish grey	10
Total thickness	320

The top of the section is at a depth of 4,360 feet and is 676 feet below sea-level. This is 28 feet lower than the top of the Jurassic at the Twin Province No. 1 well, and 226 feet lower than the top of the Jurassic intersected by the Roth and Faurot No. 2 well at Medicine Hat (sec. 8, tp. 13, rge. 6, W. 4th mer.) 30 miles north and 12 miles west of the Eagle Butte No. 2 well. At that well the section is as follows (Hume, 1933, p. 152):

Description	Thickness Feet
Sandstone, with some shale and dolomite	5
Shale, reddish brown and light greenish, with some sandstone and dolomite	10
Sand, very fine	20
Clay shale, buff and brown, calcareous	60
Sandstone, grey; with dark grey shale (oil show)	10
Shale, grey, calcareous; with pyrite	20
Fine, white quartz sand; water at 3,065 feet	10
Sandstone, grey and reddish stained	80
Total	215

The top of this section is at a depth of 2,935 feet and is 450 feet below sea-level.

Sanderson (1931) and Russell (Russell and Landes, 1940, p. 16) have shown that the Jurassic strata underlying the southern Alberta plains can be correlated with the Ellis formation of Montana. The Ellis of Montana is considered to be Upper Jurassic (Peale, 1896; Clapp, Bevan, and Lambert, 1921, pp. 63-65). Russell states that fossils from the upper part of a section of Jurassic beds exposed along Sage Creek, on the east side of the Sweetgrass Hills, Montana, correlate with the lower part of the Callovian stage in European chronology (C. H. Crickmay, 1931). This would be lower Upper Jurassic. Wickenden (1933), however, has described the Jurassic foraminifera from Eagle Butte No. 2, Northwest Boundary No. 1, and a deep well at Moose Jaw, Saskatchewan. He finds that this fauna is practically the same for all three wells, and that it compares with the Dogger of central Europe and Bajocien of France, that is, lower Middle Jurassic. Wickenden further states this fauna is very similar to that described by J. R. Sandidge (1933) from the Sundance formation in southeastern Montana. Sandidge has determined the age of his fauna to be Bajocien. It would appear, therefore, that the Jurassic of southwestern Saskatchewan includes beds older than at least the upper part of the Ellis of northern Montana. This would seem to agree with the correlation suggested for the Jurassic encountered in the Twin Province No. 1 well.

LOWER CRETACEOUS

The Lower Cretaceous beds of the Plains are known only from deep-well samples. In general, they change from entirely non-marine beds in the west to partly non-marine and partly marine beds in the middle and eastern parts of the Plains. It is, consequently, difficult to correlate sections in the east with those of western or Foothills areas.

Though wells are widely spaced, the information they provide has been interpreted to indicate three Lower Cretaceous zones in the Plains (Fraser *et al.*, 1935). These, in descending order, are stated to be:

(1) Non-marine grey sand and shale with coal.
(2) Marine, mostly grey shale with *Haplophragmoides gigas* fauna.
(3) Non-marine, grey sand and variegated shale.

In the Cypress Lake area, however, though the marine and lower non-marine zones are well defined, the uppermost zone is less distinctive, lacks diagnostic foraminifera, and fails to conform to the above zoning in that it does not contain coal. In the deep wells of this area, therefore, a sandy shale zone containing chert pebbles overlying the marine Lower Cretaceous zone is placed in a doubtful age category.

The only sections penetrated within the map-area are those in the Twin Province No. 1 and Northwest Boundary No. 1 wells. The section in the latter well, as presented in the log of the well (*See* Appendix), consists of three zones totalling 670 feet, from a depth of 3,080 to 3,750 feet. The bottom zone, 220 feet thick and chiefly non-marine, consists of dark grey, green, and red shale, volcanic ash, and, near the base, 20 feet of grey, quartzose sandstone. Overlying this zone is 320 feet of marine dark grey shale with Lower Cretaceous foraminifera. The top zone, of questionable Lower Cretaceous age, is 130 feet thick and consists of interbedded fine sandstone and dark grey shale with a chert pebble zone at the top.

The top of the section, at a depth of 3,080 feet, is at an elevation of 324 feet below sea-level. It is difficult to place the contact between the Upper and Lower Cretaceous, but it lies somewhere within or at the top of the upper 130 feet of the above section. The contact has been placed tentatively at the top of a thin layer of sand containing chert pebbles that may mark the position of a slight interval of erosion. However, the lower part of the Upper Cretaceous west of this well and south, in Montana, is characterized by numerous thin sand layers interbedded with marine shales and is generally referred to as the "Blackleaf" member. Chert-pebble beds are common at the top of this member. It becomes a question, therefore, in the absence of foraminifera, as to which lithological change marks the contact.

The upper 450 feet of this section is largely marine, whereas the lower 220 feet is chiefly non-marine and appears to contain a large proportion of volcanic material.

The Lower Cretaceous section penetrated by the Twin Province No. 1 well according to Wickenden (*See* well log in Appendix) consists of a lower 110 feet of non-marine, red, green, and grey shale with 42 feet of grey to buff, fine-grained sandstone at the base. Above this is 320 feet of grey shale and sandstone with Lower Cretaceous foraminifera, then 140 feet of grey shale and sand, in part glauconitic, with a thin bed of chert pebbles at the top. The total thickness of the three zones is 580 feet, and that of the two lower zones, definitely Lower Cretaceous in age, is 440 feet. The top of the section, at a depth of 2,710 feet, is at an elevation of 58 feet below sea-level. As at the Northwest Boundary No. 1 well the upper contact of the Lower Cretaceous is placed at the top of the sand bed containing chert pebbles. The correlation of this horizon within the limits of the Cypress Lake map-area should be fairly reliable.

Wickenden first recognized the presence of marine beds in the Lower Cretaceous of this area. The identification of a marine facies this far south was based on the presence of *Haplophragmoides gigas*, a Lower Cretaceous foraminifera first identified by J. A. Cushman (1927) from the British Petroleums No. 3 well, sec. 29, tp. 45, rge. 6, W. 4th mer., in the Wainwright field of east-central Alberta. In this well the fauna was found in shales lying beneath the "Viking sandstone" and containing small, polished chert and quartzite pebbles. The base of the "Viking sandstone" was there considered the base of the Alberta group of chiefly marine shales, and the top of the Lower Cretaceous. McLearn (1919, p. 4) pointed out the possible correlation of the Dunvegan sandstone, which overlies the St. John (Shaftesbury) marine shale of Lower Cretaceous age in the Peace River district, with the Pelican sandstone of Athabaska Valley. The

Pelican sandstone overlies the Pelican shale of Lower Cretaceous age. Hume (1933, p. 233) later indicated that the Viking sandstone in east-central Alberta occupies the same stratigraphic position as the Dunvegan and Pelican sandstones.

The 140 feet of shale underlying the Viking sandstone, and containing the chert pebbles, would, therefore, have the same stratigraphic position as the Shaftesbury and Pelican marine shales of Lower Cretaceous age. Cushman's identification of the Lower Cretaceous *Haplophragmoides gigas* fauna in these beds, therefore, appears to confirm the correlation previously suspected. McLearn (1944) in a recent revision of the Lower Cretaceous in the western interior of Canada continues to draw the base of the Upper Cretaceous at the base of the Dunvegan sandstone. Wickenden recently identified the Lower Cretaceous *Haplophragmoides gigas* fauna in the Pelican shale at the Deca No. 1 and Deca No. 2 wells near the town of Athabaska, Alberta (M. Feniak, 1944, p. 8).

Wickenden's identification of the *Haplophragmoides gigas* fauna in the marine shales immediately overlying the non-marine varicoloured Lower Cretaceous shales in the Twin Province No. 1 and Northwest Boundary No. 1 wells further extends the Lower Cretaceous, Shaftesbury sea through the Wainwright field southward into the southwest corner of Saskatchewan. The limits or areal extent of this late Lower Cretaceous sea to the southeast and west of the Cypress Lake map-area are as yet only imperfectly known.

Within the map-area the lower, non-marine part of the Lower Cretaceous thins from 220 feet, in the Northwest Boundary No. 1 well, to 110 feet in the Twin Province No. 1 well some 65 miles north, or at the rate of less than 2 feet a mile; on the other hand, the definitely lower Cretaceous marine beds above these are 320 feet thick at the Northwest Boundary No. 1 well and 330 feet in the Twin Province No. 1 well, and, if the overlying probable Lower Cretaceous beds are included, thicken from 440 feet in the former well to 470 feet in the latter, or at the rate of about ½ foot a mile northwards.

The Signal Butte No. 1 well in Montana, 10 miles southwest of the Northwest Boundary No. 1 well, according to A. G. Postle (*See* well log in Appendix), penetrated 224 feet, at depths of 3,536 to 3,760 feet, of non-marine, red, green, and grey shale and interbedded, crossbedded, fine-grained sandstone. Overlying the non-marine strata are 306 feet of dark grey to black shale and bentonite succeeded by 109 feet of interbedded grey shale and fine-grained sandstone. The 306 feet are considered to represent the marine lower Cretaceous zone, and the 109 feet the top zone of doubtful Lower Cretaceous age, similar to the zones encountered in the Northwest Boundary No. 1 well. The total thickness of the three zones is 639 feet, and of the two lower zones is 530 feet.

As the samples from this well are not available for examination by the writer, correlation has been based entirely upon lithologic descriptions by A. G. Postle (*See* Appendix). The lower, non-marine part of the section is similar in thickness (224 feet) to that at the Imperial Boundary No. 1 well (220 feet). The overlying marine section is, however, apparently somewhat thinner (306 feet, as compared with 320 feet at that well). The same section indicates still further thickening farther north at Twin Province No. 1 well, where it is 330 feet thick. Not only do the total thicknesses of the two lower sections compare closely with those in the Northwest Boundary No. 1 well, but in the topmost zone the 9 feet of sandstone at 3,185 to 3,194 feet in the Signal Butte No. 1 well appears to occupy the same stratigraphic position as the 20 feet of sandstone at 3,170 to 3,190 feet in the Northwest Boundary No. 1 well. The top of the sandstone in both wells is 40 to 45 feet above the probable marine part of the Lower Cretaceous. In this well the upper contact has been drawn at the base of a 31-foot section of hard, dark grey, calcareous sandstone extending from a depth of 3,090 to 3,121 feet.

The lower non-marine part of the Lower Cretaceous, as indicated in the above well logs, is composed largely of varicoloured shales with some lignite, indicative of continental deposition. Beds of this character can be traced entirely across southern Alberta to the Blairmore area, where they comprise the Blairmore group. However, the exact correlation and upper and lower limits are not known. In the Blairmore area these beds are underlain by the Kootenay, coal-bearing formation, a formation not yet recognized in the Alberta plains. Salt and pepper and quartzose sandstones are common in the lower or basal part of the varicoloured shale beds. These sandstones include the "Cutbank" and "Taber" type of cherty, salt and pepper sandstone, which is known to be petroliferous at places in Montana and southern Alberta, and an overlying quartzose sandstone commonly referred to as the "Sunburst sandstone", also petroliferous in Montana and parts of southern Alberta. The two sandstones, where both are present, are commonly separated by a varicoloured, yellow, red, and green shale zone. The Cutbank type sandstone has not yet been found east of the Sweetgrass arch in Montana, though this is not the case in Alberta. It is doubtful, however, if this sandstone will be found as far east as the Cypress Lake map-area.

McLearn (1944) has placed the "Pelican shale" in late Albian (late Upper Cretaceous) time in his revised correlation table. As this shale contains a boreal fauna, it is probable that the sea in which the shale was deposited transgressed from north to south upon the non-marine Lower Cretaceous beds. It may be assumed, therefore, that the sea reached the Cypress Lake map-area in quite late Albian time.

CHAPTER IV

UPPER CRETACEOUS STRATIGRAPHY

ALBERTA FORMATION

Name. The name "Alberta shale" was given by Hume (1930) to a thick section of dark grey marine shales and sandy shales lying between the Blairmore group and the Belly River formation of the Foothills. Prior to this time the beds had been known as "Benton" shales, a term derived from the "Fort Benton" of the upper Missouri River in the United States and not strictly applicable, as it designated strata only of Colorado age, whereas the "Alberta shale" is now known to include Montana beds in its upper part. In the Foothills the "Alberta shale" was thought of as comprising a lower shale formation of Colorado age; an intermediate sandstone, or sandstone and shale, member containing the diagnostic fossil *Cardium pauperculum* and referred to as the "Cardium sandstone"; and an upper shale formation that together with the "Cardium" is mainly of Colorado age, but includes, at the top, strata of Montana age. In recent years these three Alberta components have been identified, respectively, with the Blackstone, Bighorn, and Wapiabi formations of the Foothills west of Edmonton (G. S. Malloch, 1911; J. A. Allan, 1922; Rutherford, 1924; MacKay, 1929, 1930) and are referred to under these names. In the Plains area, where the "Cardium" or Bighorn sandstone is not recognized, the threefold division is lacking, and the series of shales is referred to as the Alberta formation.

Distribution and Thickness. Except for a few small outcrops on the north flank of the West Butte of the Sweetgrass Hills, in tp. 1, rge. 12, W. 4th mer., the Alberta formation is known only from deep well samples throughout the Plains of western Canada. It has great areal extent, crossing the entire western Plains of Canada and extending well into the Foothills. Its stratigraphic equivalent, in the United States, likewise underlies a vast extent of the western Great Plains and Foothills areas.

In the southern Foothills of Alberta the stratigraphic equivalent of the Alberta is 2,500 to 3,000 feet thick, whereas in the southern Alberta plains the formation, comprising the marine shales and sands lying between the continental Lower Cretaceous and the Upper Cretaceous, Milk River formation, is 1,500 to 1,800 feet thick. In eastern Alberta the basal strata of the formation have, as previously indicated, proved difficult to distinguish from marine beds of Lower Cretaceous age.

Two wells in the Cypress Lake map-area have penetrated the entire Alberta formation. At Twin Province No. 1 well, the section from the top of the basal continental Lower Cretaceous to the top of the Alberta is 1,595 feet thick. However, as shown previously, the lower 330 feet of this section is known to be marine and of Lower Cretaceous age. An additional 140 feet of sand and shale may be either Upper or Lower Cretaceous in age. The Alberta formation in this well is, therefore, 1,125 to 1,265 feet thick. Similarly, at the Northwest Boundary No. 1 well, the section from the top of the continental Lower Cretaceous to the top of the Alberta formation is 1,730 feet thick, of which the lower 320 feet is known to be marine and of Lower Cretaceous age, and the succeeding 130 feet of doubtful age. The Alberta formation is, therefore, 1,280 to 1,410 feet thick.

Lithology and Contacts. The Alberta formation consists chiefly of dark grey marine shales. Numerous beds of marine sandstone and sandy shale occur in the lower few hundred feet. This part may be correlated with the "Blackleaf" member of Montana and includes the Bow Island sandstone beds of southeastern Alberta. Two prominent calcareous zones, characterized by specks of white chalky calcite, provide excellent marker horizons for structural and stratigraphic studies. The upper contact of the formation is drawn at the top of the uppermost speckled zone, above which is a transition from marine shale into non-marine beds that marks the base of the Milk River formation. The second or lower white speckled shale zone lies some 800 to 900 feet below the top of the other speckled zone and is generally associated with calcareous, sandy beds.

The lower contact of the Alberta formation with the underlying Lower Cretaceous beds is, as previously noted, difficult to place within the map-area. Marine shales of Lower Cretaceous age here overlie continental Lower Cretaceous beds, and the distinction between the Upper Cretaceous (Alberta) and the Lower Cretaceous marine shales is based entirely upon micro-fossils. Where these are absent the contact is placed arbitrarily at some horizon that might be assumed to mark an interval of erosion, such as chert-pebble or sandstone beds.

The above features are best illustrated by sections from the deep well drilled in and near the map-area.

The Northwest Boundary No. 1 well intersected a complete section of the Alberta formation consisting chiefly of dark grey shale, 1,280 feet thick or 1,410 feet if the lower 130 feet of sandy beds are included (*See* well log in Appendix). The top of the section is at a depth of 1,800 feet and is 976 feet above sea-level. The upper contact of the formation is taken at the top of the first or upper, white speckled zone, 270 feet thick. Upper Cretaceous micro-fauna of the *Clavulina* and *Bullopora* zone were recognized by Wickenden (1932) 200 feet below the top of the speckled shale beds.

The contact with the underlying Lower Cretaceous, as previously discussed, is somewhere within the strata comprising the 260 feet between depths of 2,950 and 3,210 feet. Upper Cretaceous micro-fossils occur to a depth of 2,950 feet. According to Wickenden, these included two pelagic species, *Globigerina cretacea* d'Orbigny and *Gumbelina globulosa* (Ehrenburg). Lower Cretaceous micro-fossils occur at a depth of 3,210 feet. The contact is drawn tentatively at the top of the chert-pebble zone at 3,080 to 3,090 feet. Fish scales were noted at a depth of 2,270 feet, or 470 feet below the top of the formation.

The section penetrated by the Twin Province No. 1 well is given in the well log in the Appendix. The top of the formation, drawn at the top of the upper white speckled zone at a depth of 1,585 feet, is 1,057 feet above sea-level. The upper speckled zone is here in two parts, 180 and 190 feet thick, respectively, separated by 145 feet of unspeckled shale. A calcareous shale zone commencing at a depth of about 2,565 feet appears to mark the top of the lower or second speckled shale zone. The formation here has a drilling thickness of 1,125 to 1,265 feet, depending on whether the lower 140 feet of interbedded sand and shale below the chert-pebble zone at 2,710 to 2,720 feet is of Upper or Lower Cretaceous age. It consists essentially of dark grey shale.

Description of the samples from the Signal Butte No. 1 well in Montana by A. G. Postle (*See* well log in Appendix) includes no reference to speckled shales. If, however, the thickness of the Upper Cretaceous marine shales in this well is comparable to that of the Alberta formation in the nearby Northwest Boundary No. 1 well, the top should be drawn at a depth of approximately 1,830 feet. Postle states that from a depth of 1,830 to 2,280 feet the rock is chiefly soft black shale, with very minor amounts of very fine sand and silt. Calcite has been

recognized in soft, black, slightly silty shale, from 2,280 to 2,390 feet, or 450 feet below the assumed top of the formation. This may represent the speckled shale that is present in the Northwest Boundary No. 1 well at 2,160 to 2,280 feet, or 370 feet below the top of the formation. From 2,390 feet to 3,090 feet the samples are described as chiefly dark grey shale with some thin beds of sandy shale. Thirty-one feet of hard grey to dark grey sandstone are present from 3,090 to 3,121 feet. As previously discussed, the top of the interbedded shale and sandstone section, 109 feet thick, of doubtful Lower Cretaceous age is drawn at the base of this sandstone.

Correlation and Age. The micro-faunas identified in well samples from the Alberta formation in or near the Cypress Lake map-area have not been found in equivalent stratigraphic horizons in the Foothills sections of western Alberta, nor have the macro-faunas from these western sections been recognized in the Saskatchewan wells. Consequently, the correlation between the two districts has rested largely on lithology and stratigraphic relations to the underlying Lower Cretaceous beds. Even the first, or upper, white speckled zone which serves as an excellent datum throughout most of the Plains, becomes difficult to recognize west of Lethbridge due to the increase of sandstone beds.

The "Alberta shale" of the Foothills has been zoned on the basis of its macro-fossils (Warren and Rutherford, 1928; McLearn, 1929; Webb and Hertlein, 1934; and Russell and Landes, 1940). McLearn, more recently (1943), made a detailed study of the *Inocerami* of the Cretaceous. The ammonite zones and corresponding *Inoceramus* zones are briefly as follows:

Formation		Ammonites	Inocerami	Approximate equivalent in European chronology	
Upper Cretaceous	Belly River-Brazeau	*Baculites ovatus* and *Desmoscaphites bassleri*	*I. lundbreckensis*	Senonian	Santonian
	Wapiabi				
	Bighorn	*Scaphites ventricosus*	*I. pontoni*		Coniacian-Emscherian
	Blackstone	*Prionotropis* sp.	*I. labiatus*	Turonian	
		Watinoceras sp.			
		Dunveganoceras albertense		Cenomanian	
			I. dunveganensis		

The lower, or second, white speckled zone of the Plains occurs within the *Inoceramus labiatus* zone (Webb and Hertlein, 1934). Collier (1929) presents a list of fossils collected from the Colorado shale in the Kevin-Sunburst field, Montana. Here he shows that *Inoceramus labiatus* Schlotheim occurs within a zone 1,000 to 1,100 feet below the top of the formation, and *Scaphites ventricosus* from 20 to 750 feet below the top.

On the basis of micro-faunas, Wickenden (1941) has correlated the upper, white speckled zone of the Alberta formation with the Boyne member of the Vermilion River formation in Manitoba; the central, dark grey shale zone with the Morden member of the same formation; and the lower speckled zone with the Favel formation that underlies the Vermilion River.

MILK RIVER, PAKOWKI, AND LEA PARK FORMATIONS

The Milk River formation overlies Alberta shales in southern Alberta. There it consists of light grey to buff sandstones, green and grey shales, and lignite, and has a total thickness of from 300 to 500 feet of, chiefly, non-marine beds. These beds are best exposed along Milk River and Verdigris Coulée, Alberta. The formation is commonly divided into two members, of which the upper consists largely of shale with interbedded sandstones and some lignite beds. The lower member comprises thick, massive, sandstone beds underlain by interbedded sandstones and shales that form a transition zone into the Alberta shale. The upper contact of the formation with the overlying Pakowki marine shales is generally, though not everywhere, marked by the presence of thin beds of grey to black chert pebbles. The typical non-marine beds of the Milk River formation pass laterally from west to east across southern Alberta into dark grey marine shales. Here they become almost indistinguishable from the underlying Alberta marine shales and the overlying Pakowki marine shales. However, the chert-pebble zone at the contact with the Pakowki shale persists into Saskatchewan and provides the chief lithological feature for the recognition of the contact.

A narrow-ranging foraminiferal fauna, which contains *Epistomina caracolla*, also serves to correlate the marine shale equivalents of Saskatchewan with the Milk River formation of southern Alberta (Wickenden, 1932 and 1941).

The Pakowki formation was first recognized and described by Dowling (1917, p. 41) from exposures near Pakowki Lake. The formation is of marine origin and consists chiefly of dark grey shale with occasional thin beds of sandstone, siltstone, and bentonite. In Alberta, it thickens eastwards from 160 feet along Verdigris Coulée to 230 feet in the Foremost area. The lower contact, as previously noted, is commonly marked by thin beds of small, grey to black chert pebbles. The upper contact with overlying Foremost beds is transitional, characterized by thinly interbedded sandstones and shales. It seems evident that the eastward thickening of the Pakowki is to a large extent at the expense of the overlying Foremost formation, as the brackish to non-marine sandstones and shales at the base of the Foremost give place eastward to marine shales.

The name "Lea Park" is given to the marine shale equivalents of the Milk River and Pakowki formations in Saskatchewan and northeastern Alberta. The Lea Park lies above the Alberta formation; it underlies the Foremost formation in the south, and the Ribstone Creek formation in the north-central parts of Saskatchewan and Alberta, and no doubt includes marine equivalents, at its top, of both the latter formations. The type locality of the Lea Park is on North Saskatchewan River, between Lea Park and Battleford (Allan, 1918). However, only its upper part is here exposed, and throughout a large part of the Plains it can be studied only from well samples (Hume and Hage, 1941).

In the Lloydminster area of Saskatchewan, the Lea Park formation is reported to be 800 to 870 feet thick (Wickenden, 1941). It can generally be divided into two parts that differ somewhat in both lithology and contained micro-fauna. The lower part consists of medium to dark grey shale with numerous concretions and, at many places, chert pebbles near its top. The *Epistomina caracolla* fauna is present throughout, indicating general equivalence of this part of the formation with the Milk River of southern Alberta. The upper part of the Lea Park consists of medium grey shale overlain by sandy shale with irregular concretions and contains *Verneuilina bearpawensis* Wickenden (Wickenden, 1941).

Where complete well sections are available for study, the Pakowki and Milk River formations can be separated on a basis of micro-faunal evidence and by the

identification of the chert-pebble zone at the contact, but such is not the case when only isolated outcrops of the dark grey marine shales are available for examination. It was, therefore, considered advisable to use the term "Lea Park" for outcrops of dark grey marine shales of this age within the Cypress Lake map-area.

The following discussion will apply to the entire stratigraphic interval from the top of the Alberta to the base of the Foremost formations, and the probable subdivision of the beds into Milk River and Pakowki equivalents will be indicated.

Both the Twin Province No. 1 and Northwest Boundary No. 1 wells penetrated complete sections of the Lea Park formation. The section in the Twin Province well extends from a depth of 725 feet to 1,585 feet for a total thickness of 860 feet (*See* well log in Appendix). The top of the section is 1,967 feet above sea-level. It consists of 560 feet of medium grey shale with foraminifera in the top 75 feet, underlain by 50 feet of grey shale, chert pebbles, and glauconitic brown siltstone, then by 250 feet of grey shale and interbedded sandstone and siltstone, generally glauconitic. The top of the Lea Park is here taken at the contact of the medium grey shale with the overlying grey sandstone of the Foremost formation. This is 90 feet below the lowest coal seam. The lower contact was taken at the top of the upper or first speckled shale zone of the Alberta formation. Glauconite, as noted above, was found in small amounts for 300 feet above this contact. The chert pebbles from 1,285 to 1,335 feet are correlated with the chert-pebble zone at the top of the Milk River formation in Alberta. The marine equivalent of the Milk River formation is here, therefore, 300 feet thick, and the Pakowki equivalent 560 feet. However, the excessive thickness of the Pakowki is obviously due to the inclusion of marine shales that are the marine equivalents of the lower beds of the non-marine Foremost formation farther west. This was a time of regression of the great inland seas.

The Lea Park in the Northwest Boundary No. 1 well, between the depths 990 to 1,800 feet, is 810 feet thick and its top is 1,786 feet above sea-level. The detailed section is presented in the well log in the Appendix. The formation consists of 500 feet of medium to dark grey shale overlying 310 feet of grey shale with some interbedded grey sandstone, at the top of which is a thin, chert-pebble zone. Contacts were drawn as in the Twin Province No. 1 well. A zone of pronounced slickensiding, at 1,230 to 1,240 feet, probably marks the position of the "Woodpile Creek" fault along which the overlying beds have thrust northwards and upwards. For this reason and the fact that the beds above the fault are probably not horizontal, the thickness indicated may not represent the true thickness, and a direct comparison should not, therefore, be drawn with the section in the Twin Province No 1 well. Though no glauconite was recognized in this well section, the zone at 1,490 to 1,500 feet, containing the brown siltstone and a few chert pebbles, appears to be roughly the equivalent of the chert pebble zone at the top of the Milk River formation of Alberta and of the zone at 1,285 to 1,335 feet in the Twin Province No. 1 well. The top of the zone in both wells is approximately 300 feet above the top of the upper speckled shale zone of the Alberta formation. Wickenden has identified *Epistomina caracolla*, the typical Milk River fauna of eastern Alberta, at a depth of about 1,500 feet. These beds, therefore, comprise the equivalent of the Milk River formation in Alberta; the overlying 500 feet of shale then includes the equivalent of the Pakowki of Alberta.

The recognition of the Lea Park beds in the Signal Butte No. 1 well, across the border in Montana, is not possible from the sample descriptions available. However, it would appear that at least the beds between depths of 1,190 and 1,830 feet belong to the Lea Park formation. This interval represents an

unusually thin section for the Lea Park, and other beds should no doubt be included. The section across this interval is given in detail in the well log in the Appendix. It consists chiefly of dark grey to black shale and interbedded sandstone.

In subdividing the Lea Park in this map-area into Pakowki and Milk River equivalents for correlation with sections in Alberta, the base of the Pakowki and top of the Milk River would be drawn at a depth of 1,285 feet, in the Twin Province No. 1 well, at the chert pebbles and sandstone-bearing zone, and at a depth of 1,490 feet in the Northwest Boundary No. 1 well, at the chert-pebble zone. The respective thicknesses would then be:

	Twin Province No. 1 Well Feet	*Northwest Boundary No. 1 Well* Feet
Pakowki	560	500 (faulting)
Milk River	300	310

These thicknesses may be compared, for example, with those in the Taber area of Alberta where the Milk River formation is 360 feet thick, and the Pakowki is 200 feet thick. Russell (1939, p. 86) noted the presence of an indurated surface and chert pebbles at the contact of the two formations, and observed that the Pakowki sea transgressed an old erosion surface on the Milk River formation. Russell further interpreted the thick zone of interfingered marine and non-marine or brackish water beds at the Pakowki-Foremost contact as suggesting that the regression of this same sea was relatively slow compared with its transgression of the Milk River with which the Pakowki beds are in sharp contact. The slight change in thickness of the interval from the chert-pebble zone to the top of the first or upper speckled shale zone (top of Alberta formation), only some 50 feet in more than 100 miles, suggests that this horizon may approach a time horizon.

Part of the Lea Park is poorly exposed in the upturned strata south of the thrust fault crossing Woodpile Creek in the SE. $\frac{1}{4}$ sec. 8, and the SW. $\frac{1}{4}$ sec. 9, tp. 1, rge. 27. The stratigraphically lowest exposures occur on the northeast slopes of the creek, about the middle of the SE. $\frac{1}{4}$ sec. 8. Here a large exposure of rusty to yellow-buff weathering, dark grey, hard, argillaceous sandstone strikes south 84 degrees east and dips 45 degrees south. As the dip is nearly parallel to the slope of the hill, a thickness of only a few feet is exposed. Numerous impressions of *Baculites* sp. were noted, but only two specimens, too poor for species identification, were collected. Three hundred feet south of this outcrop, on the southwest side of the creek, is a 23-foot section of reddish coated, blue-grey weathering, dark brownish grey shale in which melanterite is abundant. Four feet above the base is a layer of reddish purple weathering, buff to grey concretions. These beds strike about south 70 degrees east and dip 32 degrees southwest. If an average dip of 40 degrees is assumed, then the beds lie about 400 feet stratigraphically above those of the lowest exposures on Woodpile Creek. East of this outcrop, on the east side of the creek, is a third outcrop of strata believed to belong to the Lea Park. Here the beds strike north 70 degrees east and dip 46 degrees southeast. The section is as follows:

	Thickness Feet
Concretions, bright brown weathering, calcareous, dark grey, siltstone	1·0
Shale, fissile, dark brownish grey to black	7·0
Shale, friable to fissile, reddish coated, blue-grey weathering, black	7·0
Concretionary layer, greenish grey to buff weathering, grey siltstone; cone-in-cone layer at top; a few fragments of pelecypods	0·8
Shale, reddish coated, blue-grey weathering, friable to fissile, dark brownish grey to black	24·8

The base of this section is stratigraphically about 370 feet above the first outcrop described. The first outcrop above this section is 205 feet to the south and consists of Foremost sandstone beds dipping 47 degrees south. If an average dip of 46 degrees south is assumed, then the sandstone would be 148 feet stratigraphically above the top of the nearest exposed Lea Park shale section and the contact between the two formations would lie somewhere within this interval. The total thickness of Lea Park strata, as represented by these outcrops, is, therefore, probably less than 518 feet.

OLDMAN AND FOREMOST FORMATIONS

The Oldman and Foremost beds, though exposed over a large part of southeastern Alberta, are confined to only small areas along the western boundary of Saskatchewan. They were included originally (1885) in Dawson's Belly River series. Later, Dowling (1915, 1917) redefined the Belly River to include the Milk River and Pakowki formations and the overlying strata, which he subdivided into the "Foremost" and "Pale and Yellow" beds, the latter subsequently being contracted to "Pale" beds. This subdivision was based on a distinctive colour difference, noted also by Dawson, between the upper and lower assemblages of beds lying between the Pakowki and Bearpaw formations; the lower or Foremost beds are generally of sombre shade in contrast with the light colours of the overlying Pale beds. Though Dowling mapped the two separately, he referred to them only as "divisions" or "facies". Williams and Dyer (1930) restricted the name Belly River to the Foremost and Pale beds. They recognized that the two "are more or less alike and the boundary between them is by no means definite", but considered it desirable to map them separately. As a result of this variable usage, Russell (Russell and Landes, 1940) regarded the term Belly River as ambiguous and elevated the two members or "facies" of this unit to the rank of formations, calling them, respectively, Foremost and Oldman formations, the latter a geographic name substituted for the more purely descriptive "Pale" beds. Though the Foremost is more argillaceous than the Oldman, the chief distinctive feature is one of colour. In Alberta the contact between them is drawn arbitrarily at the base of a massive sandstone member, which is lenticular in habit, and which is not continuous as far east as the Cypress Lake map-area. Here no satisfactory line of subdivision has been found, though in general the dominant characters of the two formations can be recognized.

In Montana the beds lying between the Claggett (Pakowki) and Bearpaw formations are known as the Judith River formation (T. W. Stanton and J. B. Hatcher, 1903 and 1905).

The lithology of the Foremost is variable, and although containing much shale, it is predominantly arenaceous. It contains numerous coal seams; fresh and brackish water fossils are abundant; and marine gasteropods and pelecypods common. In southern Alberta Russell placed the lower contact of the Foremost at the base of a sandstone member that underlies a thin indurated band and overlies marine Pakowki shale. The upper contact is placed at the upper limit of a zone of dark shale rich in carbonaceous beds and coal seams. This is in accordance with Dawson (1885, part C, pp. 44, 45) and Dowling (1917, p. 32). Williams and Dyer (1930), however, place the contact at the base of a thick, massive, lenticular, brown sandstone about 150 feet higher. Russell (1940, pp. 67, 68) likewise places the contact at the base of massive sandstone members along both Oldman and Milk Rivers. The sandstone member along Milk River he names the Comrey sandstone. It is doubtful if these members are at the same stratigraphic horizon.

The Oldman formation consists of shales and sandstones, with the latter predominant. The sandstones are commonly coarsely crossbedded and lenti-

cular. Most of the coal occurs near the top of the formation. Fossil molluscs present are largely freshwater types. Like the Foremost, the Oldman represents a period of continued non-marine conditions of sedimentation and compared with the Pakowki, a time of greatly restricted seas in the central Plains.

No sharp delineation of the contact between the two formations is possible in the Cypress Lake area. They are, consequently, discussed under the joint heading of Oldman and Foremost.

Distribution. Oldman and Foremost beds are exposed in two places within the map-area; along Boxelder Creek, in secs. 18 and 19, tp. 11, rge. 29, and along Woodpile Creek in secs. 4 and 9, tp. 1, rge. 27. Several wells have penetrated these beds in the area, but only from two of them, Twin Province No. 1 and Northwest Boundary No. 1, are much reliable or complete data available.

General Description. Oldman and Foremost beds are in general much more argillaceous here than their stratigraphic equivalents in Alberta. The shales are medium to dark grey, brown, and greenish. Bentonite shales are common, as are beds of bentonite. The shale is commonly thinly interbedded with silt and sandstone. Organic and carbonaceous shales are abundant and grade into lignite beds. The sandstones are generally buff to brown weathering, fine- to medium-grained, well indurated, salt and pepper and grey to greenish grey rocks. They usually form massive, coarsely crossbedded, lenticular beds as much as 30 feet thick, but in part are relatively thin bedded. Near the base of the Foremost formation they are in large part glauconitic. Hard siltstone layers, commonly fossiliferous, and beds of brown weathering, limonitic concretions are numerous. Lignite is abundant throughout the two formations, and although seams near the top are mined, in general these are thinner and less extensive than those mined in Alberta from the same horizons. Some intraformational shale conglomerate beds are present. In contrast with the Alberta sections, the upper Oldman beds contain much more shale than those at intermediate and lower horizons.

Dawson (1875, p. 116) noted the presence of drops of amber in the lignite and black carbonaceous shale beds, indicating the derivation of some of the lignite and organic matter from conifers.

Though the Oldman and Foremost beds in general represent non-marine conditions of sedimentation and trace westward into the thick non-marine Belly River formation of the Alberta Foothills, they are here in part of brackish and marine origin. Fossils indicative of such conditions have been identified from these beds as exposed on Woodpile Creek (Williams and Dyer, 1930, pp. 30, 31). Wickenden (*See* log of Twin Province No. 1 well in Appendix) has recognized marine foraminifera from the shales in the lower part of the Foremost. Glauconitic sandstones interbedded with carbonaceous shales occur for 250 feet above the base of this formation.

Thickness. The entire Oldman-Foremost section is indicated from surface exposures to have a thickness, along Woodpile Creek, in excess of 980 feet, though this measurement is not reliable because of thrust faulting. Another section of upturned beds, 820 feet thick, was measured along a coulée ¼ mile east of Woodpile Creek. The Northwest Boundary No. 1 well commenced near the top of the Oldman formation and showed a drilled thickness of 950 feet of beds to the base of the Foremost. The calculated true aggregate thickness of the two formations at this well site is, as shall be indicated later, between 750 and 800 feet. At the Twin Province No. 1 well 585 feet of Oldman and Foremost beds were penetrated, representing a thinning of about 200 feet, or at the rate of more than 3 feet a mile, in a northerly direction.

Detailed Description. On Boxelder Creek only the topmost beds immediately underlying the Bearpaw formation are exposed. A section on the north side of the creek in sec. 19, tp. 11, rge. 29, is as follows:

Bearpaw	Thickness Feet
Shale, dark grey to brownish grey; some silt	12·0
Oldman	
Organic shale, brown, bentonitic	1·5
Shale, grey, some sand; grades up to brown shale	2·6
Organic layer, brown	1·0
Sand, shaly, grey, and shale with organic laminæ	2·5
Covered	5·5
Finely interbedded, grey, shaly sand, grey shale, and brown organic material; mica common; some yellow silt	33·0

A poor section at the Bearpaw contact in section 19, on the east side of Boxelder Creek, exposes the following:

Bearpaw	Thickness Feet
Shale, dark brownish grey	9·5
Largely covered, but apparently mainly shale	3·0
Shale, greenish grey, bentonitic	1·0
Oldman	
Brown, organic layer, comminuted lignite	1·8
Greenish grey, sandy shale, bentonitic at top	4·2
Shale, brown, organic	2·0

A few small exposures of Oldman sandstone occur farther south along Boxelder Creek.

Several sections were measured along Woodpile Creek and nearby coulées in the upturned strata south of the thrust fault (*See* Figure 4). The beds have been disturbed by the thrust faulting and now stand at angles of 48 degrees and less. Though the main fault plane lies within the Lea Park formation, minor faulting undoubtedly occurred in the overlying beds, so that too much reliance cannot be placed upon thicknesses indicated in the sections. Furthermore, though true thicknesses were measured where possible, in many instances they were calculated from horizontal measurements. The section on the west side of Woodpile Creek, in sec. 9, tp. 1, rge. 27, is as follows:

Bearpaw	Thickness Feet
Shale (mainly)	112·0
Concealed	10·0
Oldman and Foremost	
Organic shale, brown, paper thin; little lignite	2·0
Shale, grey to light grey, sandy; some silt	4·0
Siltstone concretionary layer, brown	0·2
Shale, grey to light grey, sandy	2·3
Volcanic ash, partly altered to green bentonite	0·5
Shale, grey to light grey, sandy	3·0
Siltstone, buff to brown, with limonite	0·7
Shale, organic, brown, fissile	2·6
Shale, dark brownish grey	0·5
Shale, grey to greenish grey, sandy, limonite	11·0
Organic shale, black to brown, fissile; some lignite	6·3
Shale, bentonitic, greenish grey; silt	4·0
Shale, white weathering, sandy, grey	3·0
Shale, dark grey weathering, brown, with particles of brown organic material	2·5

Oldman and Foremost—Continued	Thickness Feet
Shale, organic, brown, fissile; some black lignitic material	4·5
Interbedded light grey weathering shale and fine shaly sandstone, with organic particles	5·5
Shale, organic, brown; with laminæ of lignite	7·0
Shale and silt, grey	2·5
Siltstone layer, chocolate-brown	0·3
Shale, grey; siltstone layer	2·0+
Concealed	109·85
Sandstone, buff weathering	5·0
Concretionary layer, dark brownish grey siltstone	0·8
Sandstone, grey to buff, very fine to shaly	8·7
Concretionary layer, chocolate-brown siltstone	0·5
Interbedded, dark grey shale and buff to grey, silty, fine sandstone, grey weathering	6·0
Shale, dark grey, grading up into grey, very fine sandstone, light grey weathering	12·7
Sandstone, brown weathering, hard, thinly bedded, slightly crumpled, very fine, brownish grey	1·3
Shale and limonitic siltstone, interbedded	1·4
Shale, dark grey	0·3
Bentonite, pale green	0·5
Shale, green, with particles of lignite, grey weathering	21·3
Shale, grey	2·6
Concretionary layer, brown siltstone	0·7
Sandstone, very fine, light grey weathering, pale grey; thin grey siltstone layer at 4·5 feet	5·0
Concealed	8·0
Shale, greenish grey to dark grey; fragments of shells and lignite in lower part; brown siltstone layer 0·5 foot thick, 8 feet above base.	10·0
Lignite, in ¼-inch seams; silt; shale; much limonite; shell fragments.	2·0
Coquina	0·1
Shale, green; shell fragments	0·2
Coquina	0·1
Shale, green and brown; fragments of shells; lignite	1·2
Lignite; some brown shale	0·3
Shale, brownish grey and greenish grey; lignite particles; shell fragments; few ¼-inch lignite laminæ	1·3
Shale, green	1·6
Shale, mottled yellow and reddish brown, with much brown organic material	1·0
Shale, organic, red to purple; fine lignite particles	1·0
Shale, grey-green	4·5
Lignite	0·1
Shale, reddish grey	1·0
Concealed	1·0
Shale, greyish green	8·6
Concretionary layer, brown silstone, limonite	1·4
Shale, greenish to dark grey	10·0
Concealed	13·0
Sandstone, very fine, pale grey, greenish grey, and buff; hard brown siltstone layers	7·0
Concealed	7·7
Sandstone, argillaceous, buff to grey	2·5
Sandstone, pale grey, very fine, compacted	2·3
Sandstone, hard, dark reddish brown weathering, brownish grey, medium-grained; upper surface pitted	0·7
Concealed	39·2
Interbedded greenish brown to greenish grey shale, silt, and fine sandstone; 6-inch beds; crossbedded at top; contains layer of buff siltstone concretions	7·5
Sandstone, coarse, crossbedded	2·5
Sandstone, fine to medium, greenish brown; limonite nodules	2·5
Sandstone, grey	2·3
Sandstone, buff, argillaceous; limonite nodules	1·0
Sandstone, pale grey, medium to coarse	1·0
Concretionary layer, reddish brown	0·5
Sandstone, pale grey to reddish brown, hard, medium-grained	9·0

Oldman and Foremost—Concluded	Thickness Feet
Sandstone, greenish brown, hard, coarse	6·0
Concealed	34·0
Sandstone greenish brown to buff, soft, fine-grained; limonite nodules.	5·0 ±
Siltstone, buff to brown	1·0
Sandstone, pale grey to greenish brown and reddish brown, medium- to coarse-grained, thinly bedded at middle, but coarsely bedded at top and bottom; crossbedded at bottom; limonite nodules	12·0
Conglomerate, buff to brown fine sandstone with light-coloured fragments of siltstone, shale, and clay pellets	1·0
Sandstone, very hard, coarse, brown weathering, massive	6·0+
Total Oldman and Foremost beds	580·1

The above beds strike east and dip from 42 to 46 degrees south. Three hundred and four feet stratigraphically below this section and 1,100 feet west is the following 14-foot section in which the beds strike east and dip 43 degrees south:

	Thickness Feet
Sandstone, dark brown weathering, fine- to medium-grained, hard, with conglomerate-like beds containing angular fragments of light grey, buff and brown siltstone and clay; numerous fragments of fossilized wood, stems, etc	2·0
Sandstone, greenish grey, compacted	6·0
Concretions, brown, medium-grained sandstone, 7 feet across	2·0
Sandstone, greenish brown, compacted	4·0

This section is approximately 150 feet stratigraphically above the first exposures of Lea Park shale to the north.

A section along the east side of Woodpile Creek, about 800 feet from the other main section, strikes slightly north of east and has an average dip of 49 degrees south. It exposes the following:

Bearpaw	Thickness Feet
Shale, mainly, dark grey; bentonite and volcanic ash	90·7
Oldman and Foremost	
Shale, organic, brown, fissile	0·8
Shale, grey, silty to sandy; siltstone layer	6·3
Shale, finely banded, fissile, grey and dark greenish grey	2·0
Shale, dark brownish grey	1·7
Shale, organic, brown and black; lignite	2·4
Shale, dark grey, interbanded with shaly, greenish grey sandstone	5·7
Siltstone, limonitic	0·6
Shale, dark grey	0·5
Siltstone, limonitic	0·5
Shale, dark brownish grey to dark grey	3·6
Shale, organic, dark brown to black, fissile; little lignite	6·5
Shale, greenish grey, bentonitic, weathering dark grey	13·3
Concretions, brown, clay-ironstone; limonite	0·5
Shale, grey, hard, friable, silty	5·6
Shale, organic, fissile, chocolate-brown	5·3
Carbonaceous band, black, fissile	1·0
Shale, grey, interbedded with fissile brown and yellow mottled and brown organic shale	3·0
Shale, organic, brown, fissile; black, carbonaceous, fissile shale	9·0
Concealed (lignite seam?)	7·5
Shale, grey, sandy; dark brown siltstone	1·0
Concealed	7·3
Shale, grey, sandy; limonitic siltstone	19·5
Siltstone, hard, brown; limonite	0·8
Shale, grey	3·0
Shale and lignite, black, fissile, carbonaceous	7·0

Oldman and Foremost—Concluded	Thickness Feet
Shale, brown, organic, fissile	3·0
Concealed	19·4
Shale, grey; chocolate-brown siltstone	10·0
Shale, brown and black, carbonaceous, fissile	4·0
Shale, grey	2·5
Organic shale, brownish grey and mottled yellow and brown, fissile	3·6
Sandstone, grey to buff, fine to medium	3·0
Shale, brown, fissile, organic; with lignite	3·3
Shale, dark brown to black, organic, bentonitic weathering	5·1
Lignite	0·2
Shale, brown, organic, fissile	15·0
Shale, greenish grey, sandy	15·7
Sandstone, grey to brown, hard	0·7
Siltstone, dark brown; silt	1·0
Sandstone, fine, buff, grading up to silt	14·0
Shale, grey to greenish	3·6
Shale, organic, brown, fissile	1·0
Shale, grey to greenish grey	5·0
Concealed	46·5
Shale, pale grey weathering, grey to greenish grey, silty	12·5
Sandstone, grey to yellow-buff, shaly; lenses of hard, thinly bedded, crossbedded to massive, grey to brown, fine- to medium-grained.	35·0
Concealed	77·2
Interbedded grey to greenish grey shale and sandy shale	15·0
Sandstone, finely crossbedded, hard, brown, medium-grained	5·5
Shale, grey and green, silty, interbedded with buff sandy shale	6·3
Shale bentonitic, green	4·0
Shale, grey, sandy	5·7
Siltstone, buff and grey	2·4
Interbedded lenses of pale grey to white weathering shale, buff, sandy shale, and yellow weathering, buff, fine silts and sands; limonite; chocolate-brown siltstone	36·4
Sandstone, silty, yellow weathering	6·0
Sandstone, hard, reddish brown	1·0
Sandstone, grey to buff	9·5
Sandstone, grey, coarse, with large brown ovoid sandstone concretions, medium-grained, platy and crossbedded	6·0
Total Oldman (?) beds	493·5

The next outcrop is 540 feet north of the above section, or about 360 feet stratigraphically below it. The beds in this outcrop strike north 73 to 80 degrees east and dip 45 to 50 degrees southeast. The section is as follows:

	Thickness Feet
Concretions, ivory to buff weathering, grey	1·0
Shale, blue-grey to brownish weathering, dark brownish grey and black, fissile	4·2
Bentonite, yellow and ivory	0·1
Shale, blue-grey to brownish weathering, dark brownish grey and black, fissile	5·8
Concealed	7·2
Shale, blue-grey weathering, very dark grey to black, friable to fissile; some melanterite	2·0
Shale, brown, organic, fissile, much brown organic material; limonite.	0·8
Sandstone, light grey, fine- to medium-grained	0·5
Sandstone, brown and greenish brown, coarse-grained, finely bedded, finely crossbedded	21·2
Sandstone, brown weathering, brown to grey, very fine-grained, compacted to indurated; numerous lenses of hard, platy, fine sandstone	39·0
Concealed	42·0
Sandstone ,hard, platy, fine-grained, buff	2·0
Total Oldman and Foremost beds	125·8

The base of this section is 205 feet south and approximately 148 feet stratigraphically above the most southerly outcrop of Lea Park shale. The entire section representing the Oldman and Foremost beds, therefore, has a thickness of at least 980 feet. However, as large sections are concealed and there may be repetition due to faulting, little reliance can be placed upon this figure.

A third section was measured in a coulée 1,600 feet east of the above section along Woodpile Creek. The strike of the beds is, in general, east, but, whereas the beds at the south end of the section dip at angles as high as 48 degrees south, those at the north end of the section dip as low as 37 degrees south. As along Woodpile Creek the north or lower part of the section is not well exposed. It is as follows:

	Thickness Feet
Bearpaw	
Shale, chiefly, dark grey; bentonite beds	72·2
Oldman and Foremost	
Shale, brown, organic; melanterite	1·2
Shale, dark grey, silty, bentonitic weathering; selenite crystals abundant	1·4
Bentonite, dark green	0·2
Shale, black and brown, fissile, organic	0·6
Shale, dark greenish grey; shell fragments	0·4
Silt; limonite; shell fragments	0·5
Shale, dark grey	0·3
Shale, carbonaceous, black, fissile	0·2
Shale, organic, brown, fissile	1·0
Shale, greenish grey, soft	3·0
Shale, brown, organic; black particles organic matter	1·8
Shale, dark grey	2·6
Coquina layer; silt; limonite	0·8
Shale, greenish grey; shell fragments, limonite	4·0
Shale, dark reddish brown with yellow spots; fragments of black organic material; shell fragments	3·3
Shale, brown, organic, fissile	4·0
Black carbonaceous matter	2·0
Shale, dark grey, bentonitic weathering	4·0
Interbedded grey and greenish grey shale, silt, greenish grey to buff sandstone, and brown organic laminæ	19·5
Sandstone, buff-grey; greenish grey shale near top	23·3
Shale, brown, organic	0·5
Lignite (shaft seam)	1·5
Shale, brownish grey with organic particles	1·6
Shale, grey; silt; limonite	5·0
Concealed	5·2
Shale, black, lignitic, fissile	2·0
Shale, brown, fissile, with yellow spots, grading down into grey shale.	7·6
Concealed; grey shale poorly exposed at places	24·0
Lignite, partly mined out	1·0+
Concealed	108·0
Sandstone, hard, buff to brown, ripple-marked, silty	1·0
Shale, grey, silty; buff silt	1·0
Shale, organic, fissile, purplish brown	3·0
Sandstone, greenish grey, argillaceous	1·7
Shale, greenish grey, sandy	3·7
Shale, reddish brown to purple, with yellow spots; organic shale; black carbonaceous shale and lignite, 2 inches thick, at top	2·0
Shale, green, bentonitic	4·1
Shale, brownish grey spotted with yellow; shell fragments; organic fragments	9·5
Shale, light greenish grey with abundant shell fragments at places in lenses; organic fragments; fragments of lignite; limonite	1·5
Shale, grey; sandy lenses	2·0
Shale, brown, organic, fissile	1·0
Shale, pea-green shell fragments	2·9
Sandstone, greenish grey, fine- to medium-grained	1·0

Oldman and Foremost—Concluded	Thickness Feet
Limonite; silt	1·0
Shale, green, grading down into greenish grey, argillaceous sandstone.	3·5
Interbedded light grey weathering grey shale and sandstone; volcanic ash	3·5
Limonite; silt	1·0
Shale, green, sandy	2·5
Sandstone, grey; little interbedded shale; organic laminæ	4·8
Shale, green, sandy	2.5
Shale, dark reddish brown; with brown organic matter	1·7
Shale, grey; particles of black organic matter	2·3
Concealed, but appears to be largely shale	17·3
Sandstone, hard, brown, medium-grained	2·5
Sandstone, hard, grey, medium-grained	3·3
Concealed	42·0
Interbedded grey and pale yellow shales and soft fine sandstones	17·0
Total Oldman beds	369·8

A small, three-compartment inclined shaft (depth not known) has been sunk on the lignite seam indicated in the above section as the "Shaft seam". The shaft is about 200 feet east of the above section. The lignite there dips 48 degrees south and strikes south 83 degrees east. In the shaft is a 2-foot seam of good lignite. Overlying the lignite is grey to buff, medium-grained sandstone with brown organic laminæ and buff-coloured clay or siltstone balls, 2 inches in diameter, at the base. Below the lignite 2 feet of brown, organic shale is exposed.

The section north and stratigraphically below that detailed above continues along the west side of the small coulée, as follows:

	Thickness Feet
Siltstone, buff	2·0
Shale, green and yellowish green; lignitic material	28·0
Shale, brown, organic; black, lignitic matter	1·5
Shale, pea-green	3·7
Sandstone, grey, crossbedded; with brown organic laminæ; interbedded at top with green shale	5·2
Shale, green	7·0
Sandstone, grey; brown, organic laminæ	6·0
Shale, greenish grey, bentonitic weathering; yellowish green to greenish grey shale; lignitic matter; small, brown, siltstone concretions	17·3
Sandstone, grey, compacted	9·5
Concretionary layer, siltstone and sandstone; hematite abundant	0·5
Sandstone, greenish grey to grey weathering, grey, medium- to coarse-grained, hard; large ovoid crossbedded sandstone concretions 7 feet below top; occasional layers of brown sandstone	25·1
Bentonite, pea-green to yellow	1·0
Siltstone, grey to brown; cone-in-cone layer at top 4 inches thick	2·3
Shale, pea-green	3·0
Total Oldman beds	112·1

The top of this section overlaps the bottom of the section last described, the 1·5 feet of brown organic shale underlying pea-green shale corresponding with the 1·0 foot of brown organic shale underlying pea-green shale in the previous section. The 45 to 50 feet of beds underlying the brown organic layers in both sections are generally analogous, though the concretionary bearing sandstone near the base is concealed in the former section. The above section, therefore, appears to represent the stratigraphic equivalent of that part of the previous section from 18·2 to 130·3 feet above the bottom.

Four hundred feet north along the coulée, and approximately 220 feet stratigraphically lower than the first section described above, is about 10 feet of hard,

yellow to buff weathering, brown sandstone with ovoid sandstone concretions several feet long. Three hundred and twenty feet north of this outcrop and an estimated 185 feet stratigraphically below it is 5 feet of hard, buff, medium-grained sandstone, below which is an additional 30 feet of poorly exposed sandstone. The above sections represent a stratigraphic thickness, exclusive of faulting, of 820 feet.

Two small outcrops of lignite beds, light grey shale, and buff argillaceous sandstone belonging to these formations are exposed in a small coulée $2\frac{1}{2}$ miles east of Woodpile Creek, in sec. 11, tp. 1, rge. 27. On the east side of the coulée a lignite seam $1\frac{1}{2}$ feet thick has been mined. It is overlain by 6 feet of grey to brown weathering, yellow-buff, lignite-bearing, argillaceous sandstone, and is underlain by pale grey to green, soft, friable shale.

The Northwest Boundary No. 1 and the Twin Province No. 1 wells both penetrated the Oldman and Foremost beds. Whereas, however, the latter well penetrated almost a complete section, the former commenced in Oldman beds, so that the beds at the upper Oldman contact are not represented. The section in the Northwest Boundary No. 1 well is presented in detail in the well log in the Appendix. It consists chiefly of light grey to greenish grey, fine-grained sandstone in beds as much as 100 feet thick. The sandstone beds are separated by thin beds of dark grey shale and brown organic shale. Immediately below the drift, from 40 feet to 70 feet, is abundant coquina and fine-grained sandstone. Lignite beds are numerous in the underlying 200 feet. The section has a total drilling thickness of 950 feet between the depths 40 and 990 feet. Its top is 2,736 feet above sea-level. The well lies approximately half a mile south of the Woodpile Creek fault. Between the well and the fault the beds all dip from 38 degrees south, near the well, to 45 degrees south near the fault. The average dip of the Oldman and Foremost beds penetrated in the well is, therefore, about 40 degrees south. The coquina beds and lignite at 40 to 70 feet in the well no doubt are the same beds exposed at the surface 250 feet west and slightly north of the well on the west side of Woodpile coulée at approximately 270 to 275 feet below the top of the Oldman (*See* page 31). The total thickness of inclined Oldman and Foremost beds at the Northwest Boundary No. 1 well would, therefore, be 1,220 feet, and, at the average dip of 40 degrees, the true thickness of these beds would be between 750 and 800 feet.

The Twin Province No. 1 well penetrated 585 feet of Oldman and Foremost beds between the depths of 140 and 725 feet. The detailed section is given in the log of the well in the Appendix. As in the Northwest Boundary No. 1 well the formations here consist of thick beds of sandstone, as much as 89 feet thick, separated by thin beds of dark grey shale, brown organic shale, and occasional thin lignite beds. Nine feet of lignite and grey shale is present at 76 to 85 feet below the top. The top of the Oldman is taken at the point where the first lignite was observed and sand becomes relatively abundant. This is at an elevation of 2,512 feet above sea-level. The point at which the lower contact should be drawn is difficult to determine. The presence of glauconite in the sandstones of the lower 250 feet of the section indicates that marine conditions of deposition have alternated with non-marine. Wickenden has identified marine foraminifera from 685 to 800 feet, and considerable fine-grained grey sand occurs in the samples to 835 feet. It was decided to place the contact at the bottom of the lowest non-marine beds. A considerable amount of lignite appears in the samples from 705 to 725 feet. The lower contact is thus drawn tentatively at this point.

Palæontology. Well-preserved macro-fossils are scarce in the Oldman and Foremost beds exposed within the map-area. Williams and Dyer (1930, p. 31), however, collected and identified a number of fossils from these beds in Woodpile

Creek. These include both marine and brackish to freshwater types, further confirming the evidence presented above to show the interfingering of beds deposited under marine conditions. The fossils are as follows: *Ostrea glabra* Meek and Hayden, *Anomia micronema* Meek, *Cardium speciosum* M. and H., *Corbula subtrigonalis* M. and H., *Panopaea simulatrix* Whiteaves, and *Martesia tumidifrons* Whiteaves.

BEARPAW FORMATION

Introduction. The Bearpaw formation, first named and described from Bearpaw Mountains, Montana (Stanton and Hatcher, 1903, pp. 211, 212, and 1905, pp. 13, 14), underlies more than 60 per cent of the map-area. At its type locality, in Montana, it is defined as consisting of dark clays with calcareous concretions that lie above the Judith River (Oldman and Foremost) sandstones, and have the lithologic character of the Pierre shales of South Dakota, part of which they represent. Stanton and Hatcher (1905, p. 14) state:

"It (the Bearpaw formation) is evidently the equivalent of only a part of the Pierre formation, which in South Dakota, Colorado, and elsewhere is defined to include all the strata between the Niobrara limestone and the Fox Hills sandstone. Whether the Bearpaw also includes the representative of the Fox Hills sandstone has not yet been definitely determined. Its limits are precisely the same as those of the beds in Alberta and Assiniboia described by the Canadian geologists as "Pierre-Fox Hills" group, whose thickness is estimated at 750 feet. The thickness in Montana probably approximates the Canadian estimate, but no section where an accurate measurement could be made was studied."

This statement is rather ambiguous in that it defines the Bearpaw as being equivalent to a part of the Pierre formation lying between the Niobrara limestone and the Fox Hills and then later states its limits to be "precisely the same" as those beds in Alberta described as "Pierre-Fox Hills". The latter included the Eastend formation, as it is apparent that in this region the Whitemud beds constituted the basal member of the "Laramie" group that overlay the "Pierre-Fox Hills" (McConnell, 1885, p. 26). Stanton, later (1919, p. 167) correlated the Bearpaw shale with the "upper part of the Pierre shale and the lower part of the Fox Hills sandstone". The definition of the Bearpaw-Fox Hills formations ultimately became the subject of much discussion. After a field conference between a committee of the Rocky Mountain Association of Petroleum Geologists (T. S. Lovering and others, 1932) and J. B. Reeside, Jr., agreement was reached to restrict the term "Fox Hills" formation to the horizons below which the section is predominantly grey marine shales and sandy shales of Pierre age, and above which the section consists of buff to brown sandstone and an overlying series of light grey to brown sandstone and sandy shales. The latter is identified with the Colgate member of the Fox Hills of eastern Montana and, as will subsequently be discussed, this is correlated with the Whitemud formation of Saskatchewan. The underlying buff to brown sandstone is the lower Brown Sandstone member of the eastern Montana Fox Hills, and will later in this report be correlated with the Eastend of Saskatchewan. In order to conform with the above revised definition of the Fox Hills formation, the Bearpaw is here interpeted to include all the marine, dark grey, Pierre shales below the Brown Sandstone member of the Fox Hills in eastern Montana and above the Judith River formation. This would mean that in southwestern Saskatchewan the dark grey marine shales overlying the Oldman formation and underlying the Eastend formation would belong to the Bearpaw formation.

At the western side of the Cypress Lake map-area three sandstones occur in the upper 300 feet of Bearpaw beds, and are either absent or very thin on the east side of the map-area. These are, in descending order, the Thelma, the

Belanger, and the Oxarart members. The last attains a thickness of 100 to 115 feet. As will be shown subsequently there is reason to believe that the Oxarart member correlates with the Blood Reserve sandstone formerly known as the "Fox Hills" sandstone on St. Mary River, Alberta. Correlation of the sandstone, here named the Oxarart, with the so-called "Fox Hills" of Alberta was made by most of the early investigators of the southern Alberta plains (McConnell, 1885, p. 25; Williams and Dyer, 1930, pp. 41, 42).

The apparent failure to recognize the presence of thin wedges of sandstone in the Bearpaw shales lying beneath the Eastend (Brown Sandstone) beds has led to much of the confusion in the recognition of the proper vertical stratigraphic limits of the Bearpaw formation. In eastern Montana the section through these beds is almost identical with that on the east side of the Cypress Lake map-area. In western Montana the Horsethief sandstone, the stratigraphic equivalent of the Blood Reserve sandstone, has generally been regarded as the equivalent of the Lennip sandstone (Stebinger, 1914, pp. 62-68) of central Montana and of the Fox Hills of eastern Montana. The Lennip sandstone, however, was not correlated definitely with the Fox Hills (Stone and Calvert, 1910), and it seems probable that it and the Horsethief sandstones are the stratigraphic equivalents of the Oxarart sandstone rather than of the true Fox Hills or Eastend.

Definition and General Description. The Bearpaw formation is here defined as the dark-coloured marine shales and minor intercalated marine and non-marine sandstones lying between the Oldman and Eastend formations. Its base is drawn at the top of the highest, brown, organic shale bed at the top of the Oldman. This is in accordance with former practice (Russell and Landes, p. 80). It is not certain that this everywhere marks the same stratigraphic horizon, but within the map-area the vertical interval between it and the main coal-bearing horizon near the top of the Oldman is fairly constant. The upper contact with the overlying Eastend formation is transitional, and is marked by a zone from a few feet to 50 feet thick of finely interbedded dark shale and brown, very fine sands and silt. This variation is due to the lateral thinning and pinching out of thin sand laminæ in the upper beds of the Bearpaw formation, and does not mean that the stratigraphic section is thinner where the transiton zone is thin than where the transition zone is thick. The overlying typical Eastend beds maintain a fairly uniform thickness and the contact is drawn at the top of the transition zone, where the first massive beds of fine sand appear.

The Bearpaw shale varies greatly in character from soft, bentonitic to hard, sandy, friable beds. However, in general, it is blue-grey or greenish grey weathering with, at places, a reddish brown coating, and containing considerable yellowish weathering melanterite, and gypsum. Fresh surfaces, though generally dark grey, may also be chocolate-brown and greenish grey.

Calcareous siltstone concretionary layers and clay-ironstone concretions are numerous. Many bentonite beds are present, and, though thin, are remarkably persistent. Both these and the concretionary layers proved valuable as local horizon markers. Gypsum and selenite are abundant, the latter at places forming crystals 5 inches long. Nodules of radiating fibrous barite were observed at a few places in the area. Layers of aragonite having a cone-in-cone structure are abundant in the lower part of the formation. They commonly form immediately above or below layers of concretions, and as envelopes enclosing some concretions. The aragonite appears to be most abundant in a 150-foot zone extending from 310 to 460 feet above the base of the formation. This zone may be referred to as the "aragonite zone".

Sandy shale zones and sandstone beds, both marine and partly non-marine, are common throughout the formation, particularly the upper part, and become

more numerous at the western side of the area. Two of these, the Belanger and the Oxarart members (Furnival, 1941, pp. 57-69) have proved to be important structural guides. Thin sandstone beds such as the *Ostrea patina* and *Artica ovata* sandstones in the beds immediately above the contact with the Oldman, along Boxelder Creek in the northwest corner of the map-area and west of it (Russell and Landes, 1941, pp. 79, 80), are not present along Woodpile Creek in the south part of the map-area.

Sandstone "dykes" are numerous throughout the formation and are widespread, occurring as far east as Bear Creek, north of the Cypress Hills.

Thickness. At no place in the map-area is an entire section of the Bearpaw exposed. However, a composite section from the base of the formation to the top of the Oxarart member is exposed along Boxelder Creek in the northwest part of the map-area. A comparison of this section with partial sections of the formation in other parts of the area indicates that this part of the formation is between 740 and 800 feet thick. The section from the top of the Oxarart member to the base of the overlying Eastend formation has been measured in many parts of the map-area, and in Alberta, and has been found to be everywhere 190 to 210 feet thick, with the thinner sections generally in the west. The total estimated thickness of the formation is between 940 and 1,000 feet.

Belanger Member. The Belanger member lies approximately 140 feet below the top of the Bearpaw formation. It is generally about 25 feet thick, but locally appears to thin to about 15 feet (*See* Figure 1). It is overlain and underlain by dark chocolate to dark brownish grey shales.

The member outcrops along the south slopes of the Cypress Hills, in Frenchman River Valley, around Cypress Lake, immediately west of Oxarart Creek, and along Battle Creek (*See* Plate II A). On the north side of the hills it is exposed at the headwaters of McShane and Gap Creeks. It is well exposed at the west end of Old Man On His Back Plateau and again along Coteau Creek at the west end of Boundary Plateau.

The Belanger member has distinctive lithological characters. On weathered surfaces it appears as a light brown to tan mixture of shaly sandstone and small, irregularly distributed fragments of dark shale. A dark brown weathering, fossiliferous, concretionary layer is present about 10 feet above the base.

The member is exposed along both sides of Belanger Creek. On the west side, in sec. 36, tp. 6, rge. 26, is the following section, measured from top to bottom:

	Thickness Feet
Shale (mainly)	48·0
Belanger Member	
Sandstone, greyish brown and greenish grey with irregular-shaped masses of dark brown shale; melanterite and selenite are common.	18·0
Concretionary layer, calcareous siltstone, dark grey, highly fossiliferous	1·5
Sandstone, brown; with dark shale fragments	1·0+

The Belanger member is represented, in part, by the lowest 20·5 feet of the above section. On the west side of Davis Creek, in sec. 32, tp. 6, rge. 25, an outcrop of the Bearpaw gives the following section, from top to bottom:

	Thickness Feet
Shale, dark greenish brown to black	90·0

Belanger Member	Thickness Feet
Sandstone, banded greenish to brownish, fine- to medium-textured, with thin irregular layers of dark shale	18·0
Concretionary layer, brown weathering, greenish grey, calcareous siltstone; highly fossiliferous	2·0
Sandstone, mainly brown, with irregular masses of dark shale (to base Belanger member)	3·5
Shale, dark chocolate-brown to black	8·0+

The Belanger member is here represented by the 23·5 feet of beds lying below the 90 feet of shale.

On the east side of Sucker Creek, in the SW. ¼ sec. 36, tp. 6, rge. 26, is the following section of Bearpaw beds:

	Thickness Feet
Shale, dark brownish grey, friable	24·0
Belanger Member	
Sandstone, brown with intermixed grey shale	4·5
Shale, dark grey	1·7
Sandstone, brown to yellowish brown, fine-grained, with masses generally rectangular and as large as 2·5 by 0·6 feet of greenish grey to grey, medium-grained sandstone with much melanterite; also present are numerous irregular small masses of dark shale; at places, and near the base, the dark shale is poorly interbedded with the brown sandstone	14·9
Concretionary layer, dark grey siltstone to fine sandstone, calcareous.	0·9

The upper part of the Belanger member is here represented by the lowest 22 feet of beds.

The above three sections, although only one is complete, serve to illustrate the character of the member. It appears to be made up of four constituents: light brown, fine sand; slightly coarser, greenish grey sandstone; dark-coloured shale; and a fossiliferous concretionary layer. At places the first three are interbedded, whereas at others the constituents are mixed, as in the above section. In some outcrops the greenish grey sandstone is present only in minor amount and as thin beds. In others it forms rounded masses surrounded by brown sand and shale. These are most apparent on vertical, weathered surfaces. Brown, organic material and coarse mica are common along the shale and sand laminæ and limonite-filled small seams are numerous. At the west end of Old Man On His Back Plateau, in sec. 19, tp. 3, rge. 25, numerous hollow or sand-filled, tapered, and curved cylindrical masses of dark shale as much as a half an inch across occur in the Belanger sand.

The concretionary layer differs from most other concretionary layers in the Bearpaw of this map-area. It is composed of ovoid to kidney-shaped masses, in places so closely packed as to constitute an almost continuous layer. Individual concretions range in size from a foot in diameter to 4 feet thick and 8 feet long. In the central and eastern part of the map-area the concretions are decidedly calcareous, dark grey to dark greenish grey, dense siltstone or, in a few places, very fine sandstone. These weather to a dark, rich brown, distinctive colour. In the western part of the area, along Battle Creek, and vicinity, the entire member, including the concretions, becomes more arenaceous (*See* Plate II A). Here the concretions weather to a brownish grey or dark greenish grey, and are composed of an aggregate of small rounded and angular siltstone and sandstone masses, as much as 6 inches long, in a dense siltstone groundmass. The outer margins of many of the concretions approach a fine sandstone in texture. Fragments of fossil wood and flakes of mica are common.

The concretionary layer is generally highly fossiliferous, some of the concretions containing an enormous quantity of fossils. These have been studied by McLearn, of the Geological Survey. They are listed in Table I, and the distribution of species at the various fossil localities is indicated.

Oxarart Member. The name "Oxarart" is proposed for a massive, cross-bedded sandstone with both marine and non-marine characteristics, that occurs in the Bearpaw formation 25 feet below the base of the Belanger member (*See* Plate II B). It is well exposed along a small creek about a mile west of Oxarart Creek, in secs. 18 and 19, tp. 6, rge. 27, and at the headwaters of Boxelder Creek, in sec. 11, tp. 9, rge. 30. The top, a hard, ledge-forming sandstone, outcrops at many places along the north and south slopes of Cypress Hills.

The member comprises two distinct parts. The upper part is a massive, hard, greyish green, medium-grained, glauconitic sandstone, with widespread and abundant fossil tree, plant, and root remains. Some of this material has been identified by W. A. Bell, of the Geological Survey, as *Equisetum* sp. Casts of worm burrowings, and plant forms are characteristic of the member. Among the fossils is a widely occurring type consisting of branching, nodose forms from ½ to 1 inch across. These are known as *Halymenites major*. Their occurrence in this sandstone from widely separate localities has been commented on by Sanderson (1931, p. 1255) and by J. S. Irwin (Sanderson, 1931, pp. 1262-3) and their origin has been discussed by R. W. Brown (1939, pp. 253-4), who believes they are the casts of burrowings. *Lingula* sp. was observed at places.

The lower part of the Oxarart member consists of yellowish brown to buff, crossbedded, compacted to slightly indurated, thinly bedded, fine- to medium-grained, glauconitic sandstone. A large quantity of brown, organic material is interlaminated with the sandstone, and at places in the lower part are beds of lignite 2½ feet thick and beds 4 inches thick of oyster shells. Coarse mica is common throughout.

The hard, cemented sandstone at the top of the member is everywhere in sharp contact with overlying dark-coloured shale. At places, a rusty limonitic bed is present, and the sandstone is commonly coated with limonite. At its base, the sandstone passes gradationally into dark-coloured shales. The transitional zone in the westernmost exposures is 27 feet thick and consists of finely interbedded, fine, brown sands and dark brown shale containing coarse mica flakes and brown organic laminæ.

The entire member thickens markedly toward the west (*See* Figure 1). At its easternmost exposure on Davis Creek, in sec. 29, tp. 6, rge. 25, the member has a total thickness of 20 feet, including a central 8 feet of sandy shale. Fifteen miles to the west the sandstone is 65 feet thick. Near Thelma, Alberta, 12 miles west of the western boundary of the map-area, the sandstone is 115 feet thick (*See* Plate III B). As the member thins eastward so does the hard sandstone ledge at the top; in the western part of the area this ledge is as much as 30 feet thick, but along the north shores of Cypress Lake it is only about 2 feet thick, and farther east it is replaced by a thin, calcareous, siltstone layer.

The hard, cemented, greenish grey sandstone at the top of the Oxarart member and the concretionary layer in the Belanger member both form prominent ledges. Where slumping has not occurred, the vertical distance between the two ledges over a large part of the area is consistently 35 to 40 feet.

Other Sandstone Members. Other sandstone members occur throughout the Bearpaw, but none that is of comparable value for structural and stratigraphic datum planes. The Thelma member, a grey sandstone, 40 feet thick on Thelma Creek, Alberta, is of stratigraphic interest. Its base there lies some 35 feet above the Belanger member (*See* Figure 1) and it appears to represent a sand-

stone tongue that thins out a short distance east of Battle Creek. It is 14 feet thick in exposures along Battle Creek in the middle of sec. 10, tp. 7, rge. 29, W. 3rd mer., where its base lies 34 feet above the Belanger member.

Lithologic Zones. Efforts have been made by various investigators to subdivide the Bearpaw formation into lithologic zones. These have not proved too satisfactory for broad correlations. No attempt is made to establish such zones for the entire Bearpaw section in the Cypress Lake map-area. However, attention is drawn to certain units that are of value in correlation and mapping.

The beds between the base of the Eastend formation and the base of the Oxarart member fall into natural units: the Oxarart sandstone member, the Belanger sandstone member, the Thelma sandstone member, all separated by 25 to 35 feet of shale, and, at the top, a shale member some 80 feet thick extending to the base of the Eastend formation (*See* Figure 1). Thin sandstone laminæ are present in the upper part of the 80-foot section, representing the transition zone to the Eastend. Where the Thelma member is absent this shale member is approximately 150 feet thick including the transition zone at the top.

The most prominent feature of the 625 to 750 feet of Bearpaw beds lying below the Oxarart member is a zone of dark grey shales and sandy shales in which are numerous beds of aragonite commonly having a cone-in-cone texture. This zone is indicated to be 150 to 175 feet thick and to lie some 300 feet above the base of the formation. It will be referred to subsequently as the "aragonite zone". In it bentonite beds and fossiliferous concretionary layers are relatively abundant.

The lowermost 195 feet of the Bearpaw formation consists of dark grey shale characterized by numerous sand and arenaceous shale beds, particularly in the northwestern part of the map-area, and by layers of very large, highly calcareous, fossiliferous concretions in which the most abundant fossil is *Artica ovata*. Bentonite beds are numerous. This zone may be named the *Artica ovata* zone, using the term in a broad sense to include both the lower, *Artica ovata*-bearing sandstone bed that occurs some 100 to 110 feet above the base of the formation (Williams and Dyer, 1930, p. 38), and an upper *Artica ovata*-bearing sandstone at 190 to 195 feet above the base.

Detailed Description. The upper part of the Bearpaw formation is best exposed along Frenchman River and its tributaries, around Cypress Lake, in the vicinity of Oxarart Creek, and along Battle Creek in range 29. The lower part of the formation is well exposed in a series of sections along Boxelder Creek from the top of the Oldman formation to the top of the Oxarart member. Less complete sections of the lower part of the formation are exposed along McCoy Creek, tributaries of Gap Creek, and McShane and Woodpile Creeks.

Sections exposed along Woodpile Creek from the top of the Oldman formation are as follows.

On the west side of Woodpile Creek, in sec. 9, tp. 1, rge. 27, the lower 122 feet of Bearpaw beds are poorly exposed. They consist of dark grey shale and bentonite beds and include a septarian siltstone concretionary layer, 100 feet above the base. No sandstone beds are present. The Oldman-Bearpaw contact is here placed at the highest brown organic layer, 37 to 57 feet above the highest lignite seam. These beds dip 48 degrees south.

On the opposite side of Woodpile Creek, some 800 feet east of the above section, are exposures of 140 to 155 feet of beds immediately overlying the Oldman formation. The highest, brown, organic layer is here 11 feet above the highest lignite bed and 68 feet above the main coal seam. The section is as follows:

	Thickness Feet
Shale, dark grey	3·0+
Bentonite, No. 6 (bentonite beds are numbered consecutively from the base of the formation), ivory to pale green; at base is ¼ inch of very dark green bentonite, and ⅛ inch of gypsum	0·6
Shale, dark grey	6·3
Concretions, purplish to ivory weathering grey siltstone in dark grey shale	1·0
Bentonite, No. 5, grey	0·3
Shale, blue-grey weathering, dark grey, silty	23·0
Bentonite, No. 4, grey	1·2
Shale, blue-grey weathering, black, slightly silty; melanterite abundant	27·0
Bentonite—volcanic ash No. 3, bed consists of three parts: 0·3 ft. light grey bentonite with only occasional biotite flakes; 0·5 ft. grey, volcanic ash, partly altered to bentonite, with numerous biotite flakes; and 0·3 ft. grey volcanic ash with much biotite and some limonite	1·1
Shale, black	0·8
Bentonite, No. 2, bright green; biotite flakes	0·8
Shale, dark grey, sandy	5·0
Shale, dark grey to black, silty, blue-grey weathering; selenite; buff to brownish grey, large, septarian siltstone concretions at top	17·2–27·0
Bentonite, No. 1, bright green, hard, slickensided	0·8
Shale, dark grey to black, blue-grey weathering, silty at places, limonitic laminæ	18·0–22·8
Concretions, rusty brown calcareous siltstone, septarian	2·0
Shale, dark brownish grey to black	13·7
Limonite and gypsum	1·3
Shale, dark grey weathering, dark grey to black	16·4
Shale, organic, brown, fissile (Oldman)	0·8
Total thickness Bearpaw beds	139·5–154·1

The above beds strike east and dip 40 to 45 degrees south (*See* Figure 4). The bentonite and volcanic ash beds serve as markers for correlating this section with others in the area. They are numbered consecutively from the base in the above and following sections as a convenience for reference. The thicknesses of the several units vary somewhat, due no doubt to slippage between beds during folding.

A fourth section was measured along the southeast side of a small coulée that branches off to the northeast from Woodpile Creek. The exposure crosses the south boundary of sec. 9, tp. 1, rge. 27, and is composed as follows:

	Thickness Feet
Bentonite, No. 11, ivory; fibrous gypsum	0·5
Shale, blue-grey weathering, dark grey to black, silty; melanterite	3·4
Bentonite, No. 10, grey at top, ivory and tan below	0·3
Shale, dark grey; melanterite	11·5
Bentonite, No. 9, grey	0·1
Shale, dark grey, hard, friable	5·3
Bentonite, No. 8 (b), grey	0·3
Shale, black	0·5
Bentonite, No. 8 (a), ivory	0·1
Shale, dark grey to black	18·7
Bentonite, No. 7, light brown	0·2
Shale, blue-grey weathering, dark grey; lower 6 feet distinctly sandy.	29·8
Bentonite, No. 6, yellow	0·1
Shale, dark grey to black	6·0
Bentonite, No. 5, greenish grey; ½ inch layer of fibrous gypsum at base	0·7
Shale, dark grey; grey septarian concretion at base	13·0
Concealed	47·0
(Details of beds between Nos. 2 and 5 bentonite layers are given in the preceding section)	

	Thickness Feet
Bentonite, No. 2, ivory-grey	0·8
Shale, blue-grey weathering, dark grey	12·3
Concretions, ivory weathering; large grey siltstone concretions with *Placenticeras* sp. and *Baculites* sp	1·2
Shale, blue-grey weathering, dark grey, silty; melanterite, limonite, and a little gypsum	7·0
Shale, sandy, dark grey; grades up into dark, silty shale	9·5
Shale, dark grey	2·0
Bentonite, No. 1, green, dark brown at top; fibrous gypsum at base.	0·7
Shale, blue-grey weathering, dark grey to black, with layers of brown silt	21·5
Shale, dark grey, very sandy; mottled masses of grey sand occur in the shale	8·0
Shale, dark grey to black, silty	22·3
Brown organic shale (top of Oldman formation)	
Total thickness of Bearpaw beds	222·8

The beds in the above section strike east and dip, on an average, 40 degrees south (*See* Figure 4). The section is useful, as it shows the position of the upper five bentonite layers, with respect to the base of the formation. These five layers can be traced southward in the flat-lying beds along Woodpile Creek. The lowest of them is approximately 180 feet above the base of the formation, and the highest about 220 feet above the base. The vertical interval between the lowest two bentonite layers, Nos. 1 and 2, is here 32 feet, the same as the maximum thickness in the preceding section. It would seem that the minimum distance, 22·2 feet, given in that section for this interval, is too small.

A typical section of the flat-lying beds south of the tilted strata can be found on the west side of Woodpile Creek in the middle of sec. 4, tp. 1, rge. 27, and is as follows:

	Thickness Feet
Bentonite, No. 11, cream coloured; gypsum at base; partly removed by erosion	0·2
Shale, black	4·5
Bentonite, No. 10, ivory, cream, and tan	0·4
Shale, black	8·9
Bentonite, No. 9, cream to tan	0·1
Shale, black; at base are rusty to buff weathering, grey siltstone concretions 2 feet by 0·5 foot with much limonite	4·6
Bentonite, No. 8 (b), ivory	0·2
Shale, black	0·4
Bentonite, No. 8 (a), cream	0·1
Shale, blue-grey weathering, reddish coating, dark grey to black	18·0
Bentonite, No. 7, yellow, some gypsum	0·3
Shale, blue-grey weathering, dark grey; row small hematite-rich concretions at base	9·0

A comparison of this with the previous detailed section indicates that the base of the section is about 170 feet above the base of the formation. Twenty-two hundred feet northeast of this is an outcrop at the base of which the No. 10 and No. 11 bentonite layers are exposed. The section is as follows:

	Thickness Feet
Shale, blue-grey weathering, dark grey to black; concretions occur from 15·0 to 34·0 feet above the base	42·0
Bentonite, No. 12, ivory coloured	0·1
Shale, dark grey to black	2·2
Bentonite, No. 11, yellow to ivory to tan; with irregular layers of fibrous gypsum	0·6
Shale, blue-grey weathering, dark grey to black	3·9
Bentonite, No. 10, grey to ivory	0·2
Shale, dark grey	1·0

Three smaller sections of these beds are exposed south along the creek to the International Boundary. Beds at about the same horizon are exposed along a small coulée in secs. 1 and 2, tp. 1, rge. 27, W. 3rd mer.

North of the thrust fault along Woodpile Creek, and extending to the north boundary of tp. 1, rge. 27, are numerous outcrops of nearly flat-lying dark grey shales. These contain iron-rich concretions with numerous *Baculites* sp. identified by Robinson as *B. compressus* Say. This form is very rare, if not entirely absent, in beds below the Bearpaw formation. These beds are, therefore, mapped as Bearpaw. The presence of much aragonitic cone-in-cone material suggests that the beds lie in the aragonite zone, and, therefore, some 300 feet at least above the base of the formation. It has been shown immediately preceding the above section that south of the thrust fault and at approximately the same elevation are beds only 170 to 215 feet above the base of the formation. In other words, the displacement along the south-dipping fault has elevated the beds south of the fault relative to those to the north.

A composite section of the Bearpaw formation prepared from a series of outcrops extending for approximately 16 miles along Boxelder Creek is given below. More than sixty separate sections were measured and correlated on the basis of bentonite layers, concretionary layers, cone-in-cone aragonitic layers, sand beds, etc. Elevations were carried by plane-table throughout. In spite of the great numbers of bentonite beds and concretionary layers, and variation in vertical intervals from place to place, the section should illustrate the general features of the formation and the relative positions of its prominent horizon markers.

	Thickness Feet
Sandstone (top of Oxarart member, 190 to 200 feet below top of Bearpaw formation), hard, ledge-forming, greenish grey, fine- to medium-grained, glauconitic, rusty coated; abundant white fossil wood; plant impressions; *Halymenites major* widespread; small (¼ inch) casts of burrowings; this ledge thickens at places at the expense of the underlying sandstone	12·0
Sandstone, compacted, light brown to grey, with thin laminæ of dark brown shale and organic material; hard ledges are present at places; coarse mica; log-like concretions of dark brown sandstone; lignite seams as much as 2·5 feet thick; *Ostrea* beds; *Lingula* sp	70·0
Siltstone, light grey, concretionary layer packed with oyster shells	0·8
Bentonite, light brown	0·1
Shale, grey-brown	1·0
Shale, organic, brown	0·9
Lignite, with white, silicified, fossil tree trunks standing upright and as much as 4 feet in diameter	0·5
Shale, brown, organic, grading down into brown shale	3·7
Interbedded brownish grey sandstone and dark brown shale; sandstone beds 1 foot thick; brown, organic laminæ; coarse mica (base of Oxarart member)	8·3
Interbedded dark brown shale, shaly, grey-brown sand, and silt; beds less than 2 inches thick	16·0
Shale, dark grey, slightly sandy, with occasional thin, ¼-inch beds of fine brownish grey sand	16·0
Shale, dark grey to dark brownish grey, sandy at top	16·0
Limonitic siltstone concretions; small nodules	1·0
Shale, dark grey	9·0
Concealed	20·0
Limonitic siltstone concretionary layer; small nodules	1·0
Shale, dark brown, with thin beds of fine greenish grey sand	6·0
Concealed	3·0
Concretionary layer, light grey weathering, grey siltstone, septarian; fossils rare	1·0
Interbedded greenish grey sand and dark grey shale	5·0
Shale, dark grey	19·5
Bentonite, yellow; limonite; small purple concretions	0·2

	Thickness Feet
Shale, dark grey, and interbedded sand	13·0
Concretionary layer with large, brown, calcareous, fossiliferous concretions (*Baculites compressus*, *Inoceramus* sp., *Oxytoma* sp., etc.)	2·0
Concealed	15·0
Bentonite, yellow	0·2
Shale, dark grey	8·0
Concretionary layer, siltstone, ivory-grey, septarian; non-fossiliferous.	2·0
Sand, grey to brown, and interbedded dark grey shale	10·0
Concealed	11·0
Shale, dark grey	6·0
Bentonite, yellow	0·2
Shale, dark grey	12·0
Bentonite, yellow	0·1
Shale, dark grey	11·1
Bentonite, yellow, blue at base	0·5
Shale, dark grey	8·0
Concretionary layer, grey and brownish grey weathering, dark grey, calcareous siltstone, with abundant small *Baculites* sp. and ammonites (*Pontiexites* sp. ?); pelecypods and gasteropods	1·0
Shale, dark grey	13·5
Bentonite, yellow	0·1 to 0·5
Shale, dark grey	16·0
Concretions, small purple weathering, packed with small *Inoceramus* sp. and *Baculites* sp., aragonite (top of aragonite zone)	1·0
Cone-in-cone aragonite layer	0·2
Shale, blue-grey weathering, dark grey; melanterite	22·0
Concretions, large, brown, containing abundant fossils; *Inoceramus* sp., *Baculites* sp., ammonites, and gasteropods	4·0
Cone-in-cone aragonite layer	0·2
Shale, blue-grey weathering, dark grey	16·0
Concretions, rusty to purple weathering, iron-rich, enclosed in cone-in-cone aragonitic material, fossiliferous	2·0
Bentonite, grey; limonite	0·05
Shale, dark grey	5·3
Bentonite, tan	0·1
Shale, dark grey; few fossiliferous concretions with cone-in-cone material	11·5
Bentonite, grey; limonite	0·05
Shale, dark grey	2·7
Bentonite, yellow; limonite	0·1
Shale, dark grey	6·9
Concretions, small purple to rusty weathering, iron-rich, siltstone; very fossiliferous; *Inoceramus* sp. and *Baculites* sp. abundant; some concretions surrounded by cone-in-cone material	1·5
Cone-in-cone aragonite layer	0·2
Bentonite, brownish grey; limonite	0·15
Shale, dark grey	5·1
Bentonite, brownish grey; limonite	0·05
Shale, dark grey, scattered small concretions; fossiliferous	10·0
Bentonite, brownish grey; limonite	0·15
Shale, dark grey	18·0
Concretionary layer, purple weathering, hematite-rich	1·0
Cone-in-cone aragonite layer; blue-yellow bentonite	0·5
Shale, dark grey	2·0
Bentonite, light buff to dark grey	0·1
Shale, dark grey with scattered purple, brick-red, and brown concretions, with much aragonitic cone-in-cone material, in some cases surrounding the concretions	14·0
Concretions, reddish brown to brown, siltstone; *Baculites* sp. and *Inoceramus* sp. abundant	4·0
Cone-in-cone aragonite layer	0·2
Shale, dark grey	17·0
Concretions, brick-red to brown, with numerous *Baculites* sp. and *Inoceramus* sp.	1·0
Shale, dark grey	1·0
Small nodules with much brown organic and aragonitic cone-in-cone material; limonite (base of aragonite zone)	0·5

	Thickness Feet
Shale, dark grey	33·0
Concretions, large, reddish brown to brown weathering, buff to grey, calcareous, sandstone and siltstone, containing many *Baculites compressus*, *Placenticeras* sp., etc., but no *Inoceramus* sp.; no aragonitic cone-in-cone material	4·0
Shale, grey, hard, silty, becoming quite sandy at top; melanterite	36·0
Bentonite, brownish green to yellow	0·2–0·5
Shale, hard, dark grey, silty at base	30·3
Concretionary layer, small, grey, septarian concretions; limonite	1·0
Shale, dark grey	4·5
Bentonite, green	0·1
Shale, dark grey	5·0
Concretions, large, brown, with abundant *Artica ovata* and other pelecypods; in sandy shale; upper *Artica ovata* sandy bed (top of *Artica ovata* zone)	6·0
Sand, dark brownish grey, and shaly sandstone	5·4
Siltstone, limonitic	0·5
Concealed	20·0
Shale, hard, grey, sandy	10·3
Bentonite, yellow	0·1
Shale, light grey weathering, dark grey, sandy	14·2
Bentonite, light brown to grey	0·2
Shale, dark grey, sandy	2·9
Siltstone, limonitic	0·3
Shale, dark grey, sandy	2·5
Bentonite, yellow	0·1
Shale, dark grey, silty to sandy	3·1
Concretions, *Artica ovata* zone, large, calcareous, grey sandstone concretions with abundant fossils, including many *Artica ovata* and *Baculites compressus* (lower *Artica ovata* sandstone)	5·0
Sand, light brown weathering, greenish brown, very fine; some interbedded brown sandy shale (lower *Artica ovata* sandstone)	8·2
Shale, brownish grey, bentonitic	0·5
Bentonite and partly altered volcanic ash	0·2
Sand, brown weathering, greenish brown; some interbedded dark brown shale	3·1
Shale, grey, poorly exposed	18·0
Bentonite, brownish green	0·5
Shale, dark grey	11·6
Bentonite, bright green	0·8
Shale, dark grey	4·7
Bentonite, dark grey	0·1
Shale, dark grey	0·5
Bentonite, yellow to dark greenish grey	0·5
Shale, dark grey	7·3
Bentonite, green and blue	1·5
Shale, dark grey	18·0
Sand, brown, with some dark shale	1·0
Concretions, large, brown, in brown sand	4·0
Sand, brown, some brown shale (*Ostrea patina*)	10·0
Concealed	20·0
Shale, dark grey to brownish grey, silty	12·0
Total thickness, Bearpaw beds	793·2
Oldman Formation	
Shale, brown, organic	5·1
Interbedded grey shaly sand, grey shale, and brown organic material with much mica	33·0

The sand and concretionary layer at 32 to 46 feet above the base appears to be the equivalent of the *Ostrea patina* zone described by Williams and Dyer from Ross Creek (1930, p. 38) and Russell and Landes (1941, p. 81) near Manyberries, Alberta.

A compilation of more than twenty sections in a distance of 4½ miles along the east side of McShane Creek is given below:

	Thickness Feet
Sandstone (top of Oxarart member), hard, greenish grey, glauconitic, fine- to medium-grained; numerous fragments of white fossil wood; *Halymenites major;* rusty coated casts of burrowings	6·0
Concealed	54·0
Sandstone, compacted, greenish brown; fine organic shale laminæ; mica	18·0
Concealed	8·8
Interbedded brownish grey sand and grey to brownish grey shale	5·0
Concealed	4·0
Interbedded grey and brownish grey shale and fine brownish grey sand; mica	18·0
Limonitic siltstone ledge, rusty weathering	1·0
Interbedded dark grey shale and brownish grey sand	15·0
Shale, soft, dark grey to brownish grey; little sand, becomes sandy at top	11·0
Bentonite, yellow to ivory	0·3
Shale, hard, friable, mottled greenish grey, with silty to sandy spots	11·0
Concretionary layer, light grey weathering, grey, septarian, siltstone; fossils sparse	1·0
Sand, glauconitic, yellowish brown to greenish brown; compacted and sandy dark grey shale; upper 2 feet and lower 2 feet predominantly shaly	9·5
Bentonite, cream to yellow	0·2
Shale, dark grey	5·0
Sand, light brown, and interbedded dark grey shale	5·0
Limonite and silt	0·3
Sand, light brown, and interbedded dark grey shale	5·3
Sand, light brown, argillaceous	5·0
Shale, sandy, dark grey	1·0
Bentonite, yellow	0·1
Sand, light brown, argillaceous	2·4
Bentonite, yellow	0·1
Shale, dark grey, and interbedded light brown fine sand	3·3
Shale, dark grey, sandy	2·0
Shale, dark grey, sandy, and greenish brown sand	5·7
Shale, dark grey, sandy	2·0
Bentonite, yellow	0·2
Shale, dark brownish grey to dark grey, silty	19·3
Concretions, grey, siltstone, widely spaced	1·5
Shale, dark grey, slightly sandy	6·5
Bentonite, greenish grey; biotite flakes	0·1
Shale, dark grey, sandy at places	26·0
Bentonite, light grey to pale yellow; limonite	0·2
Shale, dark brownish grey, sandy	5·0
Concretions, dark brown, hematite-rich, calcareous, siltstone, fossiliferous	1·0
Shale, sandy, dark grey	2·0
Concealed	28·0
Concretionary layer, grey, septarian, siltstone, highly fossiliferous (equivalent to the *Pontiexites* (?) layer in previous section)	1·0
Shale, dark grey	16·5
Concretions, purple, hematite-rich	1·1
Shale, dark grey	8·0
Bentonite, cream to light brown	0·1
Shale, dark grey, blue-grey weathering	5·5
Concretions, purple to dark brown, hematite-rich, fossiliferous; most are encased in aragonitic cone-in-cone material (top of aragonite zone)	1·0
Bentonite, yellow to blue	0·2
Shale, dark grey	3·0
Total thickness	326·2

The vertical interval from the top of the Oxarart member to the top of the aragonite zone in the above section is 322 feet compared with 341 feet in the preceding section measured along Boxelder Creek.

Half a mile south of the most southerly exposure of the top of the above section is an exposure of a brown, highly fossiliferous, sandstone, concretionary ledge containing a marine fauna that includes ammonites, pelecypods, and gasteropods. It holds subangular fragments of shale and siltstone. Below it is 10 feet of compacted brown to brownish grey sand. Allowing for the northward dip determined on the strata north of here, this section is less than 50 feet above the top of the Oxarart member and, therefore, occupies the same stratigraphic position as the Belanger member elsewhere, though possessing a somewhat different lithological character.

Exposures along McCoy Creek are thin and widely spaced, so that a compilation is not possible. The top of the aragonite zone is exposed in SE. ¼ sec. 7, tp. 10, rge. 28, W. 3rd mer., on the east side of the creek. Here the succession downward is:

	Thickness Feet
Concretionary layer, light brown, fossiliferous, septarian, siltstone	1·0
Shale, dark grey	32·0
Cone-in-cone aragonitic layer	0·5
Shale, dark grey	3·0
Bentonite	0·2
Shale, dark grey	8·0
Total thickness	44·7

The concretionary layer may correspond to that at 30 to 35 feet above the top of the aragonite zone in the sections along Boxelder and McShane Creeks.

In NE. ¼ sec. 7, tp. 10, rge. 28, is the following section, the top of which is 20 feet vertically above the top of the section described above:

	Thickness Feet
Shale, dark grey	18·0
Limonitic siltstone concretionary layer	1·0
Shale, dark grey	3·0
Bentonite, yellow	0·2
Shale, dark grey	21·5
Bentonite, light grey	0·4
Shale, dark grey	12·3
Concretionary layer, grey to brown, highly fossiliferous	1·5
Shale, dark grey, slightly sandy	10·5
Bentonite, light grey to yellow, with cone-in-cone aragonitic material	0·5
Total thickness	68·9

One mile north of the above section, in SW. ¼ sec. 20, tp. 10, rge. 28, and 80 feet vertically below it, is the following section entirely within the aragonite zone:

	Thickness Feet
Shale, dark grey, with a few scattered concretions	10·0+
Concretionary layer, grey-brown and purple concretions; no fossils noted	1·5
Cone-in-cone aragonitic layer	0·2
Shale, dark grey	13·3
Concretions, grey to brown, fossiliferous; with a variety of pelecypods; many *Baculites* sp.; *Placenticeras* sp. numerous	1·0
Shale, dark grey	16·0
Concretionary layer, purple to brown, to reddish brown, highly fossiliferous, with abundant *Inoceramus* sp. in addition to *Baculites* sp., *Placenticeras* sp., and a variety of pelecypods	1·0
Shale, dark grey	9·0
Cone-in-cone aragonitic layer with few purple siltstone concretions	0·2
Total	52·2

The upper part of the Bearpaw is well exposed along coulées about 2 miles west of Oxarart Creek. A composite section extending 4 miles from the middle of sec. 1, tp. 6, rge. 28, on the south side of Battle Creek, to the SW. ¼ sec. 30, tp. 6, rge. 27, north of Battle Creek, is as follows:

	Thickness Feet
Shale, dark grey to greenish grey, platy, soft	11·5
Interbedded, cream-coloured, bentonitic, fine sand and bentonitic grey shale	1·1
Shale, dark grey to dark greenish grey, platy; a few sand beds at base.	4·1
Sand, brown, with calcareous, fine, dark grey, small, siltstone concretions; no fossils noted (top of Belanger member)	0·5
Interbedded dark brownish grey shale and fine brown sand	2·0
Sand, greyish green, medium-grained, glauconitic, as irregular masses in chocolate-brown shale and fine, brown sand; some pelecypods.	5·6
Sand, brown, fine, with some intermixed shale	1·5
Concretionary ledge of dark brown weathering, calcareous, dark grey siltstone; highly fossiliferous, many pelecypods	1·5
Sand, fine, greenish brown, glauconitic; with large amount of dark grey to chocolate-brown shale, and brown organic material; coarse mica	5·0
Shale, dark greenish grey, with thin beds of fine, greenish brown sand; brown organic matter; mica flakes (base of Belanger member)	6·2
Shale, soft, dark greenish grey, thinly bedded, semi-fissile; thin layers of very fine greenish grey sand	9·1
Sand, argillaceous, fine, greenish grey	2·5
Shale, bentonitic weathering, hard, dark grey to greenish grey, with few fine, greenish brown sand beds	15·5
Rusty, limonitic layer	0·2
Sandstone, hard, greenish grey, glauconitic, fine- to medium-grained, with abundant white fossilized wood fragments as much as 10 inches across; fossil casts of burrowings ⅛ inch across; plant impressions; *Halymenites major;* rusty coated (top of Oxarart member)	25·0
Sand, compacted, greenish brown, medium-grained; brown, organic laminæ; coarse mica; numerous limonite layers	4·7
Sand, compacted, thinly bedded, strongly crossbedded, greenish grey to brownish grey, fine- to medium-grained; brown organic laminæ numerous; mica common	10·8
Sand, compacted as above, with large amount of brown organic material and comminuted lignite	1·0
Sand as above, with numerous brown organic laminæ	2·0
Sand, compacted, thinly bedded, crossbedded at places, fine- to medium-grained, greenish grey to brownish grey; medium-sized mica flakes; a few brown organic laminæ	13·2
Interbedded grey and brownish grey, finely bedded, compacted sand and dark brown to dark grey shale; brown organic laminæ; coarse mica; limonite beds	8·7
Shale, dark brown to very dark grey and greenish grey, finely interbedded with brownish grey, very fine sand and silt	7·0
Siltstone, hard, light grey	0·5
Shale, dark grey, with fine sand and silt beds; brown and black organic laminæ; mica	4·2
Finely interbedded dark greenish grey and brownish grey, fissile shale and greenish grey to brownish grey, fine sand and silt; beds 1·5 inches thick; little mica; selenite abundant	11·0
Shale, dark greenish grey, platy; occasional 1-inch beds of greenish grey sand and silt	33·0
Limonitic concretions	0·5
Shale, dark grey; selenite common	19·5
Limonitic layer, silt and shale, some nodules	0·5
Shale, dark grey	1·0
Limonitic nodular layer	0·5
Shale, soft, dark greenish grey to greenish brown	11·2
Irregularly bedded, brownish grey to greenish grey, medium-grained sandstone, and dark grey shale; selenite common	2·0
Limonitic siltstone concretions	0·6

	Thickness Feet
Shale, dark greenish brown to brownish grey, semi-fissile	6·6
Interbedded dark grey to greenish grey shale and fine greenish brown sand; limonite; melanterite	6·6
Concealed	2·3
Shale, dark grey to dark brownish grey, friable; little limonite	6·3
Interbedded shale and fine, grey to brownish grey sand; limonite; melanterite; mica	1·6
Concretionary layer, grey to dark grey siltstone; fossils rare	1·0
Interbedded dark grey to brown arenaceous shale and brown to brownish grey sand	6·2
Shale, dark brownish grey	1·3
Bentonite	0·2
Shale, dark brownish grey to grey; few thin layers of silt	12·7
Shale, dark greenish grey to dark grey; selenite crystals; some concretions near base	18·0
Total thickness	285·4

The beds from 16·7 feet to 39·4 feet below the top of the section comprise the Belanger member. If only the beds from 66·3 to 143·4 feet below the top of the section are included in the Oxarart member, it has a thickness here of some 77 feet.

The Belanger member and the overlying beds to near the top of the Bearpaw are well exposed along the north shore of Cypress Lake. A composite section there is as follows:

	Thickness Feet
Shale, dark grey to greenish grey, friable, bentonitic weathering; at top are thin silt to fine sand beds	50·0
Concretions, buff weathering, grey, septarian, siltstone	1·0
Bentonite, green	0·7
Shale, dark brownish grey, earthy weathering; some selenite	29·0
Bentonite, cream	0·5
Shale, dark brownish grey to chocolate-brown; selenite	2·7
Intermixed brown sand and dark brownish grey shale; some greenish grey sand (top of Belanger member)	8·5
Concretionary layer, dark brown weathering, calcareous, olive-green, fossiliferous, siltstone	1·2
Intermixed brown sand and dark shale; brown organic material; mica flakes; grades downwards in brownish grey shale (base of Belanger member)	13·2
Shale, dark brownish grey to dark grey	23·0
Sandstone (Oxarart sandstone member), greenish grey, hard, fine- to medium-grained, with fossil wood and lignite seams as much as 2·4 feet thick; glauconitic	8·0
Sandstone, brown, compacted; brown organic laminæ	10·0
Total thickness	147·6

The beds from 41·0 to 63·9 feet above the base of the section comprise the Belanger member.

A complete section of the Bearpaw from the Belanger member to the top of the formation was not found, but the stratigraphic distance encompassed by this zone can be measured approximately from outcrops in the NE. ¼ sec. 32, tp. 6, rge. 24, on the east side of Farewell Creek, and in NW. ¼ sec. 20, tp. 6, rge. 24, on the south side of Frenchman River. These exposures are 1½ miles apart. The Belanger sandstone member is overlain by some 80 feet of shale on Farewell Creek. The section there is as follows:

	Thickness Feet
Shale, dark greyish brown, greenish brown	56·8
Shale, dark chocolate-brown, platy; grades upwards into brownish grey shale	22·0

Belanger Member	Thickness Feet
Sand, brown, intermixed with chocolate-brown shale; limonite......	10·6
Concretionary layer, dark brown, calcareous, dark grey, siltstone....	1·2
Sand, buff, thinly interbedded with dark chocolate shale...........	8·5
Total thickness..................................	99·1

The section exposed on the south side of Frenchman River is as follows:

Eastend Formation	Thickness Feet
Sand, very fine, yellowish brown to buff..........................	13·8
Bearpaw Formation	
Interbedded, buff, very fine sand and grey shale; weathers light buff.	5·0
Interbedded brown to buff-grey shale and buff to brown silt and very fine sand..	9·0
Shale, dark greenish brown to brown; occasional layer of silt; top 5 feet becomes lighter in colour...............................	16·0
Total thickness..................................	43·8

The contact of the Bearpaw with the overlying Eastend formation is drawn at 30 feet above the base of the above section. This would be 156 feet above the top of the Belanger member, on the east side of Farewell Creek, and 202 feet above the top of the Oxarart member as indicated by the composite section from the north shore of Cypress Lake. The contact is well exposed at a number of points along Frenchman River Valley east of the above sections, and the details are presented with the description of the Eastend formation.

Limited exposures occur at the west end of Old Man On His Back Plateau, in secs. 10, 15, and 16, tp. 3, rge. 25. A compilation of these, in descending order, is as follows:

Frenchman Formation	Thickness Feet
Sandstone, medium to coarse; greenish brown, coarsely crossbedded.	34·0
Eastend Formation	
Sand, very fine, finely banded; yellowish brown to brown, compacted.	18·0
Bearpaw Formation	
Interbedded grey and dark grey shale and very fine brown sandstone.	13·0
Shale, dark grey, with thin beds of very fine light brown sand and silt.	15·5
Siltstone layer, hard, pale grey..................................	0·3
Shale, dark grey, semi-friable; few thin layers of light brown silt....	11·5
Concealed...	93·0
Shale, dark grey, semi-friable; some scattered dark grey concretions with *Baculites* sp..	10·0
Shale, dark chocolate-brown, slightly silty, lower few feet semi-fissile and contains some brown organic material....................	9·1
Intermixed brown and greenish grey argillaceous sand with particles of dark, chocolate-brown shale; limonite, melanterite, and gypsum common (Belanger member)......................	24·5
Concretionary layer, dark brown weathering, dark grey, calcareous, fossiliferous, olive-green, siltstone (Belanger member)..........	1·0
Intermixed dark brown shale, brown sand, and greenish grey, glauconitic sand (Belanger member)...........................	2·0
Concealed...	50·0
Interbedded dark greenish grey to brownish grey, semi-fissile shale and greenish brown to brownish grey, very fine sand; sand predominates; in upper 10 feet are occasional buff to brown weathering non-fossiliferous concretions............................	33·0

The lower 33 feet of the section is probably the equivalent, in part at least, of the Oxarart member to the northwest. The section from the top of the Belanger member to the base of the Eastend formation is 142 feet thick. The Belanger member is here at least 27·5 feet thick, so that allowing 25 feet to the top of the stratigraphic equivalents of the Oxarart member, which appears to be thinning out here, the interval from the base of the Eastend to the top of the Oxarart would be at least 195 feet.

The strata lying between the Oxarart member and the base of the Eastend formation in the western part of the map-area are much more arenaceous than those in the east. They are well exposed along the valley of Battle Creek, in tps. 6 and 7, rge. 29. A composite section made up from secs. 8 and 9, tp. 6, to sec. 16, tp. 7, is as follows:

	Thickness Feet
Interbedded dark grey shale and fine, greenish brown sand with beds of yellowish brown silt at top (transitional to Eastend formation)	15·0
Shale, dark grey, grades up into dark greenish grey shale with numerous thin beds of greenish grey, fine sand	20·0
Shale, dark grey; occasional thin sand beds in upper 10 feet	54·0
Sand, greenish brown with interbedded dark chocolate-brown shale; limonite and melanterite at top; beds of broken shells 1 to 2 feet below top (Thelma member)	10·0
Concretions, buff weathering, dark grey, septarian, siltstone; fossiliferous (Thelma member)	1·5
Sand, compacted, brown, fine-grained (Thelma member)	2·8
Siltstone, laminated layer, buff	0·5
Interbedded brown sandstone in beds as much as 12 inches thick; brownish grey to grey shale in beds 2 inches thick; and beds of finely bedded grey shale and grey silts	29·0
Shale, chocolate-brown with thin layers of fine brown sand	4·0
Sandstone, bluish green weathering, hard, with some irregular masses of dark grey shale, highly fossiliferous, pelecypods, gasteropods, and scaphopods (Belanger member)	1·5
Concretions, bluish grey to brown weathering, dark grey, siltstone; some have many rounded to angular masses or fragments of siltstone, shale, and even fine sandstone; highly fossiliferous (Belanger member)	1·0
Sandstone, greenish brown to brownish grey, compacted, beds as much as 18 inches thick; and grey to chocolate-brown shale as laminæ 1 inch thick; no crossbedding noted (Belanger member)	25·5
Shale, dark brown, arenaceous, with thin beds of greenish grey sand	8·0
Shale, dark grey to black, grading up to dark brown and brownish grey; occasional thin layer of fine sand	17·0
Sandstone (top of Oxarart member), hard, rusty coated, greenish grey, glauconitic; much white fossilized wood; casts of burrowings ½ and 1 inch across	4·0
Sandstone, yellowish brown to greenish brown, compacted to hard, with numerous laminæ of brown and black organic shale; coarse white mica; thin beds of grey shale	4·8
Lignite	1·0
Sandstone, purplish brown, compacted, with brown organic matter	1·0
Sandstone, compacted to hard, light greenish grey, medium-grained; fissile, brown, organic shale; mica	5·5
Sandstone, greenish brown, compacted to hard, massive, a little brown organic material	7·7
Sandstone, yellowish brown and greenish brown, fine- to medium-grained, compacted; numerous laminæ of brown and black organic matter; coarse white mica	4·9
Sandstone, compacted, greenish grey, fine- to medium-grained	1·1
Sandstone, light grey, smooth weathering, horizontally bedded, silty, hard, grey, fine	5·5

The lignite in the Oxarart member is not seen in all exposed sections, and appears to be lenticular. It has been mined in sec. 33, tp. 6, rge. 29. The beds from 25 to 53 feet above the top of the Oxarart member comprise the Belanger

member. The sand beds, 14·3 feet thick, at 33·5 to 47·8 feet above the Belanger member, appear to occupy approximately the same stratigraphic position as, and to be the eastward extension of, a sandstone member that is well developed along Thelma Creek about 3 miles south of Thelma, Alberta, in sec. 2, tp. 7, rge. 4, W. 4th mer., and on the east side of Medicine Lodge Coulée in sec. 7, tp. 8, rge. 4, W. 4th mer., Alberta. For purposes of reference this member is called the "Thelma member". The total thickness of the strata lying between the Oxarart member and the base of the Eastend formation is here 199·8 feet.

Two additional sections of the beds between the Oxarart and Eastend were measured in Alberta, one on the east side of Medicine Lodge Coulée and the other on Thelma Creek about 3 miles south of Thelma. These sections are referred to in the subsequent description of the Eastend formation.

The upper part of the Oxarart member is exposed along Fish Creek, in secs. 24 and 25, tp. 8, rge. 28, and along Petrified Coulée, in secs. 28 and 33, tp. 8, rge. 28. The composite section along Fish Creek is as follows:

Belanger Member	Thickness Feet
Intermixed dark grey shale, argillaceous sand, and greenish brown sand	5·0
Concretionary layer, dark brown weathering, dark grey, siltstone to sandstone; fossiliferous	1·0
Intermixed, dark brownish grey shale, brown argillaceous sand, and greenish brown sand; some shale occurs as scattered irregular fragments (base of Belanger member)	14·0
Shale, dark chocolate-brown grading up into dark grey; few thin layers of brown sand	12·0
Shale, dark chocolate-brown	2·0
Concealed (probably includes top of Oxarart member)	28·0
Sandstone, greenish grey, glauconitic, hard, fine- to medium-grained, rusty coated, with some hard, quartzitic layers; much white fossilized wood, some pieces as much as 12 feet long and more than a foot in diameter (Oxarart member)	22·0
Shale, black, carbonaceous, fissile	0·7
Lignite, good quality, mined	3·9
Shale, dark grey	0·5
Concealed	3·2
Shale, greenish grey, hard, friable, arenaceous	5·0
Sandstone, hard, greenish grey, medium-grained	1·9
Brown organic material	0·7
Sandstone, grey and greenish grey, fine- to medium-grained, indurated	4·6
Brown organic material	0·1
Total thickness	104·6

The beds in the upper 20 feet of the section comprise the Belanger member, and those in the lower 43 feet represent a part of the Oxarart member.

A composite section of the exposures along Petrified Coulée is as follows:

	Thickness Feet
Sand, greenish grey, argillaceous, glauconitic; hard 6-inch layers are interbedded with softer material; interbedded grey shale at base (Belanger member)	23·8
Shale, dark brownish grey and greenish grey; hard, mottled patches of fine sand	12·0
Shale, dark chocolate-brown, grading upwards into dark greenish grey; interbedded brownish grey sand in lower 2 feet	15·0
Sandstone, hard, greenish grey, glauconitic, rusty coated; much fossil wood; numerous phosphatic *Lingula* sp. (top of Oxarart member)	2·0
Sandstone, grey to greenish brown, fine- to medium-grained, cross-bedded, compacted to hard; numerous large, log-like, dark purplish brown, irregularly shaped concretions; colour changes vertically and laterally from grey to greenish brown	26·0

	Thickness Feet
Mostly concealed, but with numerous small exposures of greenish grey, brown to dark brown, compacted sandstone, and log-like sandstone concretions	30·0
Sand, grey to brownish green, compacted, with occasional layers of dark grey shale; much coarse mica; much brown organic material.	16·2
Sandstone ledge, light grey, very hard, dense to fine-grained	2·0
Sand, compacted to hard, greenish grey and buff, with numerous brown organic laminæ (bottom of Oxarart member)	8·8
Interbedded dark grey to black shale and greenish grey, fine sand; bedding 1 inch thick	10·0
Total thickness	145·8

The upper 23·8 feet of this section appears to represent the Belanger member, though the concretionary layer generally present was not observed.

The beds lying from 80 feet to about 150 feet below the top of the Oxarart member are exposed in a series of outcrops along the north side of the valley of North Fork Creek, in the north part of tp. 5, rge. 30. A composite section of these outcrops is as follows:

	Thickness Feet
Interbedded, light buff, sandy weathering, light brown, arenaceous shale and argillaceous sand; limonite layers (basal part of Oxarart member)	6·5
Bentonite, green	0·5
Shale, brownish grey, silty	1·0
Bentonite, green; limonite	0·2
Shale, brown, silty	2·0
Shale, light grey, bentonitic weathering, hard, dark grey layers; some gypsum	20·0
Concretions, dark purplish brown to rusty weathering clay ironstone; limonite abundant	1·0
Interbedded, dark grey shale and brownish grey sand passing upwards into fissile, dark grey shale with fine beds of brown sand and limonitic silt	8·9
Bentonite, yellowish green; limonite	0·1
Shale, arenaceous, light brownish grey to grey, hard, friable	9·8
Bentonite, light and dark green	0·5
Shale, arenaceous, hard, grey to brownish grey; limonite and thin fibrous gypsum layers	5·4
Shale, dark grey, bentonitic, weathering, soft	15·0
Concretionary layer, buff to grey weathering, septarian, dense, grey, siltstone; highly fossiliferous, *Baculites* sp. abundant	1·5
Total thickness	72·2

On Bear Creek, in tp. 9, rge. 23, are a number of outcrops of tilted beds of the Bearpaw and Eastend formations. Many of the outcrops are difficult to place stratigraphically, and the succession is complicated by local faulting. However, in the southwest corner of sec. 7, tp. 9, rge. 23, some 600 feet of beds are exposed, all trending north and dipping 50 to 70 degrees east. A section across these beds is as follows:

	Thickness Feet
Sand, greenish brown to brown	6·0+
Shale, dark grey	7·0
Bentonite, yellowish green, slickensided	0·7
Shale, dark grey, with irregular masses of rusty brown sandstone	5·5
Shale, with layers of brown organic material	1·7
Shale, grey, hard	2·6
Shale, brown, fissile, organic; lignite	2·3
Shale, dark grey	30·5
Concealed	13·1

	Thickness Feet
Sandstone, greyish brown to greyish green, medium-grained, compacted, finely bedded; calcareous light grey siltstone concretions; 3 feet below top contain *Inoceramus* sp. (Belanger member?)....	21·0
Concretions, rusty; sandstone, containing numerous marine fossils, *Placenticeras* sp., *Inoceramus* sp. (Belanger member?)..........	1·0
Shale, dark grey..........	4·4
Sand, compacted, pale greenish grey to brownish grey, fine-grained, glauconitic..........	5·2
Shale, dark grey..........	13·5
Bentonite, yellowish green..........	0·6
Shale, dark grey..........	4·0
Shale, grey, sandy, light buff weathering; shaly sand..........	19·5
Shale, dark grey; numerous slickensided bentonite beds; concretionary layers (there may be some repetition of beds due to faulting; thicknesses measured may exceed true thicknesses)..........	342·1
Shale with row of large, brown weathering, calcareous siltstone concretions, as much as 10 feet across; no fossils noted..........	5·0
Bentonite, brownish green..........	2·0
Shale, dark grey..........	36·8
Shale, dark grey, with layer of large, brown weathering, calcareous siltstone concretions, as above; no fossils noted..........	5·0
Bentonite, grey, with 1-inch fibrous gypsum at top..........	0·5
Shale, dark grey, hard, friable..........	8·8
Concretions, large, brown, calcareous, siltstone..........	4·3
Shale, dark grey, slightly sandy, hard, friable..........	26·0
Concretions, small, calcareous, dark grey, siltstone; highly fossiliferous; *Placenticeras meeki*, *Baculites* sp..........	1·5
Shale, dark grey..........	22·0
Thickness..........	592·6

The total thickness given for this section may be excessive due to bedding plane slippage and faulting and to the high angle of dip, which make it difficult to determine true thicknesses.

The strata lying above and to the east of this section are folded and faulted to the extent that it was not possible to complete the section. Sandstone beds, organic shale, and lignite are prominent.

The fossils collected from the upturned beds in the above section were studied by McLearn, and a list is given on a subsequent page. His conclusions are that the collections contain mostly long-ranging species that do not indicate the precise age of the enclosing rocks. What little evidence there is from the existence of shorter ranging species is in favour of a Bearpaw rather than a Pakowki age. One species, *Pecten* (*Chlamys*) *nebrascensis* Meek and Hayden, found in the shale, has only been collected from the Bearpaw, and may be exclusively of Bearpaw age. The section, therefore, appears to represent a part of the Bearpaw formation. It seems most probable that the sandstone from about 70 to 91·4 feet below the top of the section and containing the highly fossiliferous concretionary layer at its base is the Belanger member. If this is so, then the 19·5 feet of sandy shale and shaly sand at 27·7 feet below this member may be the equivalent of the Oxarart sandstone member.

Baculites compressus Say was identified from steeply dipping dark grey shales farther north on the east side of Bear Creek. These beds, at least, are, therefore, of Bearpaw age.

Palæontology. A large collection of fossils was made from the Bearpaw beds of this area. Special detailed studies of parts of this collection are continuing. Identifications made to date of the fossils are chiefly by F. H. McLearn of the Geological Survey. H. R. Robinson identified the *Baculites* and R. J. W. Douglas (1942) studied and identified certain *Inocerami*.

The presence of many highly fossiliferous horizons throughout the formation has been commented upon. Amongst these the Belanger member is one of the most prolific. The fauna from this member, as established to date, is presented in the following table (Furnival, 1941). The localities represented are all south of the Cypress Hills and east of rge. 28, W. 3rd mer. Large numbers of fossils collected from exposures of this member west of range 28 and from the northern part of the map-area have not yet been studied. Many of the species listed occur in great numbers at the various localities.

TABLE I

—	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Yoldia mcconnelli Landes?						×			×															
Yoldia sp	×			×									×				×							×
Nucula sp	×					×							×		×		×							
Gervillia sp																	×							
Gervillia borealis (Whiteaves)																					×			
Gervillia recta Meek and Hayden													×						×	×				
Inoceramus barabini																				×				
Oxytoma nebrascana Evans and Shumard	×	×	×		×				×	×	×	×	×				×	×	×	×	×			
Pteria notukeuensis Warren	×																						×	
Modiolus attenuata Meek and Hayden																				×				
Pholadomya sp																		×						
Artica ? sp		×																×						
Protocardia subquadrata Evans and Shumard	×	×		×	×								×	×		×	×		×	×	×	×	×	×
Protocardia (large new species?)							×			×										×	×			
Protocardia borealis or new sp																					×			
Protocardia sp						×																		
Tellina equilateralis Meek and Hayden	×												×				×		×	×		×	×	×
Tellina equilateralis Meek and Hayden, short var		×											×					×			×	×	×	×
Tellina cupressensis Landes					×	×			×								×			×				
Panope mclearni Warren																×								
Mactra warrenana Meek and Hayden	×	×			×		×		×				×			×				×	×			
Mactra? sp										×														
Dosiniopsis sp				×	×																×			
Acanthoscaphites sp													×						×				×	×
Acanthoscaphites nodosus var. *quadrangularis* Meek and Hayden forms a, b, and c. *a*																	×				×			
b	×	×		×													×			×				
c					×																			
Acanthoscaphites nodosus var. *plenus* Meek and Hayden forms a and b. *a*							×														×			
b	×																							
Pontiexites cf. *robustus* Warren	×																×				×			
Pontiexites cf. *gracilis* Warren																			×					
Discoscaphites ? sp																								×
Nautilus sp	×																			×				
"*Fusus*"? sp		×															×							
Anchura sp																							×	
Lunatia sp								×									×							
Lingula nitida Meek and Hayden																					×			
"*Acirsa*" sp																								×
Lunatia concinna Hall and Meek?																					×			
Dentalium sp																				×			×	

List of Fossil Localities in the Belanger Member

1. North side of Frenchman River, just west of road from Caton's ranch to Robsart, section 14-6-25W3.
2. Quarter-mile north of junction of Davis Creek and Frenchman River, east bank, section 29-6-25W3.
3. West side Davis Creek near its mouth, section 32-6-25W3.
4. West side Belanger Creek near its junction with Frenchman River, section 36-6-26W3.
5. West end Cypress Lake, north of the mouth of Oxarart Creek, section 15-6-27W3.
6. East side of creek one mile west of Oxarart Creek, section 19-6-27W3.
7. East side of creek one mile west of Oxarart Creek, section 19-6-27W3.
8. East side of creek one mile west of Oxarart Creek, section 30-6-27W3.
9. West branch of creek one mile west of Oxarart Creek, section 24-6-28W3.
10. West side of creek one mile west of Oxarart Creek, section 19-6-27W3.
11. Same locality as No. 10 but from the soft sandstone 3 feet above concretionary layer.
12. West side of coulée north of Fodrick farm, section 10-6-28W3.

13. North side Cypress Lake, section 27-6-26W3.
14. North side Cypress Lake, section 20-6-26W3.
15. North side Cypress Lake, section 30-6-26W3.
16. North side Cypress Lake, section 24-6-27W3.
17. Northwest shore Cypress Lake, section 14-6-27W3.
18. Northwest shore Cypress Lake, section 14-6-27W3.
19. Southeast shore Cypress Lake, section 14-6-26W3.
20. Southeast shore Cypress Lake, one mile west of highway No. 21, section 14-6-26W3.
21. East bank of creek 3½ miles west of Old Man On His Back Plateau, section 19-3-25W3.
22. North side of coulée 2 miles northwest of Old Man On His Back Plateau, section 16-3-25W3.
23. North side of coulée a quarter mile south of No. 22, section 16-3-25W3.
24. One hundred yards southwest of No. 23, section 16-3-25W3.

McLearn, in discussing these fossils, makes the following statements:

"The species and varieties of *Acanthoscaphites* need revision before much use can be made of them. In Table I, form 'a' of var. *quadrangularis* is much like Meek and Hayden's plate 25, figures 3, a and b. Form 'b' is more compressed and has coarser and less even costæ on the body chamber than form 'a'. Form 'c' is a compressed variety. The form 'a' of var. *plenus* appears to be much like the type, but varies much in size. The form 'b' of var. *plenus* has a thinner body whorl and lacks the inner row of nodes. *Mactra formosa* is listed as a synonym of *M. warrenana*."

The Oxarart member is generally devoid of fossils. Numerous small phosphatic specimens of *Lingula* sp. were found in the hard sandstones of this member along Petrified Coulée, in the NE. ¼ sec. 29, tp. 8, rge. 28. *Ostrea* sp. beds are locally abundant. Silicified fossil tree trunks are common in the upper beds at many places and are as much as 2 to 3 feet in diameter. An outcrop on the top of a hill immediately west of a coulée in the SE. ¼ sec. 28, tp. 9, rge. 29, exposes many scattered silicified trunks of trees, as much as 4 feet across, standing upright in a bed of brown carbonaceous shale and lignite. These would appear to have been buried in situ. Two feet above this bed a siltstone layer carries abundant oyster shells. These beds are about 42 to 45 feet above the base of the member. One of the most interesting fossils is the branching, nodose, root-like casts previously mentioned and known as *Halymenites major*. This fossil has wide lateral distribution in the map-area and in the western part of the Cypress Hills, and appears to be limited in stratigraphic section to the upper hardened surface of the Oxarart member or within a few feet of it. It has proved valuable as an aid in recognizing this horizon. R. W. Brown (1939, pp. 253, 254), discussing the origin of *Halymenites major*, finds that the central core of specimens of these fossils collected near Marmorth, North Dakota, are filled with light-coloured, irregular pellets containing 2 to 13 per cent PO_4. He suggests that the pellets may be the excrement of an animal that inhabited the burrow. Brown is not convinced that *Halymenites* is a seaweed, but on the contrary may be the branching burrow of some marine animal.

Those fossils from beds of the Bearpaw formation, in addition to those listed in the foregoing two members, that have been studied and identified are given in the following three tables.

The stratigraphic range of species of *Inoceramus* identified to date from the Bearpaw beds of the Cypress Lake map-area are presented below:

—	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Inoceramus fibrosus (Meek and Hayden)	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..
I. mclearni Douglas	..	..	..	×	..	×	×	..	..	..	..	..	..	..	..
I. mcshaniensis Douglas	..	..	..	..	..	..	×	..	..	..	..	..	..	..	..
I. furnivali Douglas	..	..	..	..	..	..	..	..	×	×	×	×	×	×	..
I. palliseri Douglas	..	..	..	..	..	..	..	×	..	×	×	×	..	×	..
I. barabini var. *inflatiformis* Douglas	..	..	..	..	..	..	..	×	×	×	×	×	×	×	..
I. barabini var. *magniumbonatus* Douglas	..	..	..	..	×	..	..	..	..	×	×	..	×	×	..
I. barabini	×	..	×	..	..	×	..	..	..	×	×	×	×	×	×

		Depth below top of Bearpaw Feet
1.	NW.¼ sec. 10, tp. 7, rge. 29, Battle Creek (Belanger member) sec. 14, tp. 6, rge. 26, south side Cypress Lake (Belanger member)	160
2.	NE.¼ sec. 27, tp. 2, rge. 24, E. side road N. of Divide	160–240
3.	NW.¼ sec. 26, tp. 9, rge. 27, McShane Creek	355
4.	SE. ¼ sec. 15, tp. 10, rge. 29, 1½ miles east of Boxelder Creek	390
5.	SE. ¼ sec. 17, tp. 10, rge. 28, Boxelder Creek	390
6.	Sec. 25, tp. 9, rge. 27, McShane Creek	475
7.	Sec. 25, tp. 9, rge. 27, McShane Creek	485

		Height above base of Bearpaw Feet
8.	NE.¼ sec. 7, tp. 10, rge. 28, McCoy Creek	480–500
9.	SE. ¼ sec. 17, tp. 10, rge. 29, Boxelder Creek	400
10.	SE. ¼ sec. 30, tp. 10, rge. 29, Boxelder Creek	390
11.	SE. ¼ sec. 30, tp. 10, rge. 29, Boxelder Creek	380
12.	SE. ¼ sec. 30, tp. 10, rge. 29, Boxelder Creek	300
13.	SE. ¼ sec. 19, tp. 10, rge. 28, McCoy Creek	300
14.	SE. ¼ sec. 30, tp. 10, rge. 29, Boxelder Creek	355
15.	SE. ¼ sec. 30, tp. 10, rge. 29, Boxelder Creek	275

H. R. Robinson made a detailed study of the *Baculites* specimens collected from the Bearpaw beds of the Cypress Lake area. In addition to *Baculites ovatus* and *Baculites compressus*, Robinson (unpublished Master's Thesis, Department of Geology, McGill University, 1942) described a new variety of *B. compressus* that he designated *B. compressus* var. *ornatus*, and a new species, *Baculites giganteus*. The following table shows the distribution and stratigraphic range of the species of *Baculites* within the map-area. The excessive abundance of *B. compressus* relative to *B. ovatus* and its stratigraphic range throughout the entire formation emphasizes its importance as a diagnostic fossil for the Bearpaw formation.

—	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Baculites ovatus	..	..	..	..	..	..	..	..	..	X	..	..	X	..	..	..	..	..	..	..	..
B. compressus	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
B. compressus var. *ornatus* Robinson	..	..	..	..	..	..	..	..	..	..	..	..	..	..	X	..	X	X	X	..	..
B. compressus var. *corrugatus* Elias	..	..	..	..	..	..	..	..	..	..	..	..	..	..	X	..	..	..	..	..	..
B. giganteus Robinson	..	..	..	X	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

		Depth below top of Bearpaw Feet
1.	Sec. 20, tp. 1, rge. 23, coulée west side Boundary Plateau	30–40
2.	Sec. 20, tp. 5, rge. 30, near Middle Creek dam	325
3.	Secs. 28, 33, tp. 5, rge. 27, Battle Creek	300–400
4.	Secs. 13, 25, 26, tp. 9, rge. 27, McShane Creek	330–360
5.	Sec. 18, tp. 9, rge. 28, west tributary of Gap Creek	360
6.	Sec. 27, tp. 9, rge. 29, west tributary of Gap Creek	425–450

		Height above base of Bearpaw Feet
7.	Sec. 34, tp. 9, rge. 29, east tributary of Boxelder Creek	480–500
8.	Sec. 29, tp. 9, rge. 29, Boxelder Creek	480–500
9.	NE.¼ sec. 7, tp. 10, rge. 28, McCoy Creek	480–500
10.	Sec. 33, tp. 9, rge. 28, coulée draining into Downey Lake	480–500
11.	SE.¼ sec. 32, tp. 9, rge. 29, Boxelder Creek	450–475
12.	Sec. 3, tp. 11, rge. 23, coulée east of Bear Creek (aragonite zone)	310–460
13.	Sec. 3, tp. 11, rge. 23, coulée east of Bear Creek (aragonite zone)	310–460
14.	Sec. 31, tp. 1, rge. 27, Woodpile Creek (aragonite zone)	310–460
15.	Sec. 36, tp. 10, rge. 29, Boxelder Creek Sec. 31, tp. 10, rge. 29, Boxelder Creek Sec. 32, tp. 10, rge. 29, Boxelder Creek	275–400 275 275

	Height above base of Bearpaw Feet
16. Sec. 32, tp. 10, rge. 29, coulée east of Boxelder Creek	275
17. Sec. 2, tp. 1, rge. 27, coulée 2 miles east of Woodpile Creek	175–250
18. Sec. 16, tp. 11, rge. 29, east tributary Boxelder Creek (lower *Artica ovata* sandstone)	100–120
19. Secs. 5, 8, 16, tp. 11, rge. 29, Boxelder Creek (lower *Artica ovata* sandstone)	100–120
20. Sec. 7, tp. 10, rge. 23, west of Bear Creek; upturned strata; stratigraphic position doubtful	
21. Sec. 7, tp. 10, rge. 23, west of Bear Creek; upturned strata; stratigraphic position doubtful	

Other fossils are as follows:

—	1	2	3	4	5	6	7
Yoldia sp.	×						
Nucula sp.				×			
Liopistha montanensis Henderson					×		
Oxytoma nebrascana Evans and Shumard					×		
Pteria linguiformis Evans and Shumard					×		
Artica ovata							×
Pecten (Chlamys) nebrascensis Meek and Hayden						×	
Lucina sp.			×				
Anomia sp.					×		
Thracia sp.					×		
Placenticeras meeki Boehm		×			×		
Placenticeras sp.			×				

1. Sec. 20, tp. 5, rge. 30, near Middle Creek dam.
2. Sec. 2, tp. 1, rge. 27, coulée tributary to Battle Creek, 1,000 feet north of International Boundary.
3. Sec. 2, tp. 1, rge. 27, coulée tributary to Battle Creek.
4. Sec. 9, tp. 3, rge. 30, southwest of Altawan.
5. Sec. 7, tp. 10, rge. 23, Bear Creek.
6. Sec. 29, tp. 10, rge. 23, Bear Creek.
7. Sec. 16, tp. 11, rge. 29, Boxelder Creek.

Though the Bearpaw formation has not been zoned on the basis of macrofossils, the number of new species defined from the studies made so far of only a part of the large number of fossils collected from the area give some promise in this respect.

R. T. D. Wickenden of the Geological Survey examined a group of samples from the Bearpaw beds for foraminifera. Four samples from the Belanger member on the south slopes of the hills yielded *Haplophragmoides* sp., *Trochammina* sp., *Reophax* sp., or *Saccammina* sp., and *Dentalina* sp. A sample of shale from the south side of a coulée 100 feet west of the east boundary of sec. 12, tp. 3, rge. 28, yielded *Haplophragmoides kirki* Wickenden, *Haplophragmoides* sp.?, *Trochammina* sp., and *Verneuilina bearpawensis* Wickenden. Another sample, from the southwest side of Thelma Creek, NW. ¼ sec. 9, tp. 3, rge. 30, contained: *Haplophragmoides fraseri*? Wickenden, *Haplophragmoides* sp.?, *Verneuilina bearpawensis* Wickenden, and *Guadryina bearpawensis* Wickenden. Wickenden points out that this fauna bears some resemblance to that in the sample from sec. 12, tp. 3, rge. 28, and states that all these species are found in the lower 100 to 150 feet of the Bearpaw formation in the Manyberries and Lethbridge districts of Alberta. Both exposures had been placed low in the stratigraphic section of the Bearpaw on lithological grounds. The beds in sec. 12, tp. 3, rge. 28, are known to lie near the base of the aragonite zone, or within 325 feet of the base of the formation.

Wickenden, further, identified *Ammodiscus cretacea* d'Orbigny in a sample taken 365 feet below the top of the Bearpaw. *Gaudryina* sp.? was found in a sample 285 feet below the top of the formation, in sec. 22, tp. 5, rge. 30, and *Trochammina albertensis* Wickenden was identified from samples near the base of the upturned Bearpaw beds on Bear Creek, in the SW. ¼ sec. 7, tp. 10, rge. 23.

Age and Correlation. Palæontological evidence exclusive of micro-fossils is of only limited value in carrying correlation beyond the map-area, as no definitely short-range species that would be of value for correlative purposes have been found in the Bearpaw beds. Many of the pelecypod species have long ranges and, as investigation proceeds, more of those formerly thought to have diagnostic value are being placed in the long-range category. In this respect it is interesting to note that the presence of *Tellina equilateralis* in the Belanger member places in the long-ranging group a fossil formerly thought (Russell and Landes, 1940) to be confined to the Pakowki formation.

Of the species listed from the Belanger member, *Lingula nitida*, *Inoceramus barabini*, *Protocardia subquadrata*, *Tellina equilateralis* Meek and Hayden, and *Mactra warrenana* Meek and Hayden, all extend down to the Pakowki formation. *Gervillia borealis* has been reported from the Claggett of Montana, and *Oxytoma nebrascana* extends even lower than the Pakowki. The Belanger member fauna shows definite affinities with faunas collected by McLearn and Warren from the high Bearpaw beds in Saskatchewan to the east of this area. A close similarity is likewise shown to Russell and Landes "Eastend" fauna of Alberta. However, as will be shown subsequently, this fauna in every case was collected from the Belanger member. *Yoldia mcconnelli*, *Tellina cupressensis*, and *Discoscaphites* are all present in Landes' fauna from the Belanger member (Russell's "Eastend") in Alberta, and the last is considered to be a high Pierre and Fox Hills genus (Russell and Landes, 1940, p. 88). *Pteria notukeuensis* and *Modiola attenuata* are present in the high Bearpaw of southern Saskatchewan (Fraser *et al.*, 1935, pp. 123-6). *Panope mclearni*, *Acanthoscaphites* var. *quadrangularis* Meek and Hayden, and *Pontiexites* all occur in Landes' fauna from the Belanger member (Russell's "Eastend") in Medicine Lodge Coulée, Alberta, as well as in the high Bearpaw of Saskatchewan.

McLearn notes that *Gervillia recta*, *Pteria notukeuensis*, *Modiola attenuata*, and *Panope mclearni* have possibilities as short-ranging, high-Bearpaw fossils, but not enough is yet known to establish them as such.

The specimens of *Inoceramus fibrosus* (Meek and Hayden) were collected from a bed of dark purplish grey, fossiliferous, hematite-rich, siltstone concretions in dark grey shale exposed in a low road-cut half a mile north of Divide, in sec. 26, tp. 2, rge. 24. This horizon is not more than 80 feet below the Belanger member, and, if any slumping has occurred, the true stratigraphic position may be much closer to the Belanger. Landes (Russell and Landes, 1940, p. 185) considers this a short-ranging species restricted to the very latest Pierre and Fox Hills beds, and though they report it from their Eastend fauna of Alberta it has apparently been collected from the stratigraphic equivalent of the Belanger member.

Though the lithology of the steeply dipping, deformed beds of dark grey marine shale and sandstone exposed along Bear Creek suggests Bearpaw age, these beds could be either Bearpaw or Pakowki equivalents. The hardened and slickensided condition of the associated bentonite beds is evidence that their attitude is not due to slumping but to deformation. The fauna from these beds was critically studied by McLearn. It includes the following: *Oxytoma nebrascana* E. and S., *Liopistha montanensis* Henderson, *Pteria linguiformis* E. and S., *Inoceramus* sp., *Placenticeras meeki* Boehm, *Anomia* sp., *Thracia* ? sp., and *Pecten (Chlamys) nebrascensis* M. and H.

McLearn points out that the first five of these species range from Pakowki or Lea Park to Bearpaw, inclusive, but that up to the present *Pecten nebrascensis* has only been collected from the Bearpaw formation, and is probably exclusively of Bearpaw age. He concludes that the little evidence available from the shorter ranging species present is in favour of a Bearpaw rather than Pakowki age.

The Bearpaw beds, as pointed out by Landes (Russell and Landes, 1940, p. 185) are characterized by abundant *Baculites compressus* and *Inoceramus barabini*. Beds containing an abundance of the former are generally of Bearpaw time. *Inoceramus barabini* is correlated with the European Campanian fauna. Douglas (1942, p. 59) places the age of his new species of *Inoceramus* as late Campanian. The new species of *Inoceramus*, namely *I. mclearni*, *I. palliseri*, *I. furnivali*, *I. barabini* var. *inflatiformis*, and *I. barabini* var. *magniumbonatus*, have as yet only been identified from Bearpaw beds.

The Bearpaw formation of the Cypress Lake map-area is correlated, on the basis of stratigraphic position and fauna, directly with the Bearpaw of Montana, for which the type locality is the Bearpaw Mountains only some 40 miles to the south. In correlating these beds westward with those in Alberta it is evident, as pointed out by Russell (1940, pp. 80, 81), that the basal beds of the formation across southern Alberta (and it appears to hold for the Cypress Lake area) are everywhere of about the same age, whereas the upper beds become younger as they are followed from west to east. It is, therefore, the correlation of the beds at the top of the formation with which the following discussion is most concerned.

The correlation of the Belanger, Oxarart, and Thelma members of the Bearpaw formation (*See* Figure 1) and the Eastend beds of the Cypress Lake map-area with the Bearpaw and Eastend beds around the west end of the Cypress Hills and east of the Sweetgrass arch is referred to subsequently under the discussion of the Eastend formation. It is shown there that the correlatives of the Oxarart, Belanger, and Thelma members have been included by Russell in his Eastend formation, and that the top of the Bearpaw formation in that area should be placed some 267 feet higher in the stratigraphic section than where he has drawn it.

Correlation of the Bearpaw beds of the Cypress Lake area with the Bearpaw beds on the west side of the Sweetgrass arch is more difficult. A composite section of the Bearpaw beds along St. Mary River has been measured and checked by Russell (1940, pp. 74, 75) who finds a total thickness of 720 feet. This section is overlain by approximately 115 feet of massive, medium-grained, grey-buff to greenish weathering sandstone that Russell has named the Blood Reserve formation and which was formerly known as the Fox Hills formation. This sandstone bears a striking lithologic resemblance to the Oxarart member of the Bearpaw formation in the Cypress Lake area. Like it the upper surface is a resistant, well-indurated, somewhat rusty ledge in which silicified fossil wood and *Halymenites major* are abundant. The striking lithologic resemblance of the two units and their almost identical stratigraphic position in the geological section suggest their correlation. The total thickness of Bearpaw and Blood Reserve beds along the St. Mary River of Alberta is approximately 835 feet, as compared with a total thickness to the top of the Oxarart member in the Cypress Lake area of Saskatchewan of 740 to 800 feet. It seems possible, therefore, that these two groups of beds are very nearly time equivalents. The marine beds extending from the Oxarart member to the base of the Eastend in the Cypress Lake map-area, as shown in this report, are replaced westward by sandstones and probably have their time equivalents in the St. Mary River area represented by certain of the lower beds of the St. Mary River formation.

The approximate Manitoba equivalents of the Cypress Lake Bearpaw beds are the Odanah and Riding Mountain beds (Wickenden, 1945) the relations of which to the Alberta Bearpaw is discussed by Landes (Russell and Landes, 1940, pp. 190, 191).

EASTEND FORMATION

The type area for the Eastend formation is near the town of Eastend, Saskatchewan, 8 miles east of the area mapped. The beds comprising this formation were termed "Fox Hills" and "Estevan" by early workers, but McLearn's studies of the stratigraphy of southern Saskatchewan indicated that these names could no longer be applied. He referred to the formation as "Sands A and D" (McLearn, 1929, 1930) and suggested that it would require a new name. Accordingly, Russell (1933) adopted the term "Eastend", the name being used for this formation in the preparation of a final report (Memoir 176, 1935) on the region. In that report (page 23) the Eastend is defined as "the fine sands and coarse silts that lie between the marine shales of the Bearpaw and the fine to medium, mostly kaolinized, non-marine sands of the Whitemud formation". The formation has marked uniformity in character throughout southern Saskatchewan.

Distribution. The Eastend is best exposed a mile northwest of Ravenscrag, along Ravenscrag Butte, and on the west side of Table Butte. Limited exposures occur along Adams and Battle Creeks, along the south side of Old Man On His Back Plateau, and in the vicinity of Boundary Plateau. A few small exposures occur along the north slopes of the Cypress Hills and in the disturbed strata on Bear Creek.

General Character. The Eastend formation is composed of beds of very fine, buff to yellowish brown sand. The texture in many places is so fine that it should more strictly be called coarse silt or superfine sand. Such beds are poorly cemented. In general they lie horizontally, and, though thinly bedded, are not uncommonly crossbedded. Limonite is abundant. At places beds of grey to greenish grey shale, commonly a foot or so thick, occur throughout and particularly near the top of the formation. Siltstone ledges and concretionary layers are common. Organic material is abundant as laminæ and thin beds, and some comminuted lignite is generally present. West of the map-area lignite beds are thicker and at places have been mined.

Poorly preserved marine fossils were found in a concretionary layer 17 feet below the top of the formation on the south side of Frenchman River Valley, on the south side of sec. 22, tp. 6, rge. 23. Marine fossils were also found in the lower part of the Eastend east of the map-area. In sharp contrast with this evidence of marine conditions of sedimentation prevailing during the deposition of the lower beds are beds of organic material and lignite in the middle and upper parts of the formation. A tooth identified by C. M. Sternberg of the Geological Survey as that of a carnivorous dinosaur was found in beds near the top of the formation on Battle Creek.

The lower contact of the Eastend with underlying dark Bearpaw shales is marked by a transitional zone varying in thickness from a few to 50 feet. The position of the contact is drawn arbitrarily at the base of the continuous sands and silts and at the top of the transition zone.

The upper contact in general consists of a transition zone only a few feet thick in which the buff silt passes upwards into the coarse white feldspathic sandstone of the Whitemud formation. At places the top of the Eastend is marked by about 3 feet of light grey shale. In places, too, this upper contact of the Eastend is with beds younger than the Whitemud, due to an interval of erosion that preceded the deposition of the Frenchman beds.

Thickness. Near Eastend the formation is 70 feet thick. On Ravenscrag Butte it is 65 feet thick, and overlies a transition zone 15 feet thick. On the west side of Table Butte, in secs. 10 and 15, tp. 6, rge. 24, it is 70 feet thick, and

the transition zone beneath is 5 feet thick. On Adams Creek, in tp. 7, rge. 28, a complete section is not exposed, but is estimated to have a thickness of 73 feet. Likewise, on Battle Creek, in tp. 7, rge. 29, a complete section is lacking and slumping has increased the difficulty of an accurate estimate, but the formation appears to be about 100 feet thick. Along the east side of Medicine Lodge Coulée, at the west end of the Cypress Hills, in Alberta, the formation is 116 to 120 feet thick (*See* Figure 1).

Detailed Description. The most complete section of the Eastend in the map-area was observed a mile northwest of Ravenscrag, in sec. 25, tp. 6, rge. 24. Details, in descending order, are as follows:

	Thickness Feet
Whitemud Formation	
No. 1 zone: white weathering, pale grey, feldspathic sand.	
Eastend Formation	
Sand, very fine, buff; becomes paler towards top	15·5
Shale, blue-grey to dark grey, grading upwards into yellowish brown shale	7·0
Sand, very fine, grey to buff, finely bedded	4·9
Interbedded brownish grey shale and brown sand; limonitic at top; ¼-inch siltstone layer	1·2
Sand, brown, very fine	4·0
Sand, buff, with thin beds of brownish grey, silty shale	2·5
Sand, buff and grey, very fine; thin laminæ of brown organic material	23·8
Sandstone, hard, finely banded, grey to buff, fine	5·0
Sand, very fine, pale buff	4·6
Bearpaw Formation	
Interbedded soft buff to grey shale and buff fine sand; yellow silt; grading down into greenish grey shale	14·2
Total thickness	82·7

The lower 14·2 feet represents beds transitional into the underlying dark shale of the Bearpaw formation. The Eastend formation is, therefore, 68·5 feet thick.

The base of the section on Ravenscrag Butte, in sec. 27, tp. 6, rge. 23, is not exposed. The section there is as follows:

	Thickness Feet
Whitemud Formation	
No. 1 zone: white weathering, pale grey, feldspathic sand.	
Eastend Formation	
Shale, medium grey, with numerous laminæ of limonite	8·1
Shale, interbedded buff and grey	3·2
Sand, uniform, very fine, yellow-brown	2·0
Brown organic material	0·2
Sand, uniform, very fine, yellow-brown	7·4
Limonitic concretionary layer	0·5
Sand, very fine, yellow-brown; some crossbedding	10·1
Shale, grey; limonitic nodules	1·0
Sand, very fine, yellow-brown; some crossbedding	28·0
Total exposed thickness	60·5

Several complete sections of the Eastend formation are exposed on the west side of Table Butte in Palisade Gap, sec. 10, tp. 6, rge. 24. The one least disturbed by slumping is on a point overlooking the Bartlett ranch house. It is as follows:

Whitemud Formation	Thickness Feet
No. 1 zone: pale grey, feldspathic sand.	
Eastend Formation	
Shale, bluish grey	3·6
Sand, very fine, compacted, buff to yellowish brown; limonite laminæ; occasional grey shale beds, siltstone beds, and, near top, brown organic material	52·0
Concretionary layer of hard, grey, finely bedded, fine- to medium-grained sandstone; limonite	6·0
Sand, very fine, buff to brown	9·1
Sand, as above, with beds of dark brownish green shale	5·0
	75·7
Bearpaw Formation	
Shale, dark.	

If the lower 5 feet of the Eastend is regarded as the transitional zone, the Eastend is here 70·7 feet thick. Other sections occur farther north on the west side of Table Butte. Glauconite was observed in some of the sand beds intercalated with shale in the zone transitional into the underlying Bearpaw shale.

The following incomplete section is exposed on the southeast side of Table Butte; the upper beds are missing.

	Thickness Feet
Concretionary ledge of hard, grey to buff, fine sandstone	3·0
Sand, very fine, buff, finely bedded, with some beds of grey shale	17·5
Sandstone, hard, fine, finely bedded	0·8
Sand, very fine, buff, finely interbedded with grey silts	7·4
Concretionary layer; hard, fine, buff to brown sandstone	7·2
Sand, fine, buff, finely bedded	4·0
Concretionary layer of hard, fine, buff sandstone	1·0
Total thickness	40·9

Below this section is a transitional zone 16·5 feet thick of interbedded buff and brown fine sands and silts and grey shales, overlying dark grey Bearpaw shale. The concretionary layer 5 feet above the base may be the same as that at 9·1 feet above the base of the previous section.

The exposures on Adams Creek occur in secs. 6, 7, and 8, tp. 7, rge. 29, on both sides of the valley. A composite section is as follows:

Whitemud Formation	Thickness Feet
No. 1 zone: light grey, feldspathic sandstone; limonite.	
Eastend Formation	
Sand, compacted to hard, greenish brown, very fine; limonite laminæ near top	12·0
Concealed	3·0
Sand, compacted, rich yellowish brown, very fine, finely bedded, crossbedded, laminæ of limonite; some beds of grey fine sand in lower 5 feet	17·0
Concealed	14·0
Sand, compacted to hard, very fine, greenish brown to bright brown, very little crossbedding; abundant limonite laminæ; few beds of grey, fine sand; limonite layer at base	27·0
Total thickness of Eastend	73·0
Bearpaw Formation	
Interbedded dark greenish grey shale and greenish grey to brownish grey, very fine sand and silt (transition zone into underlying Bearpaw formation).	

The exposures on the east side of Battle Creek, in tp. 7, rge. 29, are, as previously stated, very incomplete. A 33-foot section of the upper part of the Eastend formation is exposed on the eastern boundary of sec. 21, tp. 7, rge. 29. This consists of compacted, very fine, clean, reddish brown, horizontally bedded sand. Occasional thin shale layers and siltstone conglomerate beds are present. The lower contact and other small sections are exposed at 2 miles northwest of the above exposure in the NE. ¼ sec. 29, tp. 7, rge. 29, and again at 3 miles to the northwest in a cut bank on the east side of Battle Creek, in the middle of sec. 31, tp. 7, rge. 29. The section at this latter locality is as follows:

	Thickness Feet
Contact of Whitemud and Battle formations.	
Eastend Formation	
Whitemud formation, only partly exposed (estimated)	52·0
Concealed	91·0
Sand, compacted to hard, brown weathering, light brown, very fine, argillaceous	10·0
Bearpaw Formation (Transition Zone)	
Interbedded, fine, buff to brown, silty sand and grey, arenaceous shale; beds 2 inches thick	8·0
Interbedded dark grey shale and fine brownish grey sand and silt	7·0
Bearpaw Formation	
Shale, dark grey; very occasional ¼-inch layer of brown fine sand and silt	30·0

The transition zone is here 15 feet thick and the indicated maximum thickness for the Eastend formation is 101 feet.

Though normally the upper contact of the Eastend formation is with Whitemud beds, at places it lies unconformably beneath the Frenchman formation. This is due to a period of erosion that preceded the deposition of the Frenchman beds. Where this has occurred the Eastend may be as little as 6 feet thick, as on Old Man On His Back Plateau. The following is a section in the southeast corner of sec. 10, tp. 3, rge. 25:

	Thickness Feet
Frenchman Formation	
Sandstone, coarse-grained, brown and greenish brown; some hard layers	33·6
Eastend Formation	
Sand, very fine, finely banded, yellowish brown to brown; thin lenses of grey shale at upper contact	18·0
Bearpaw Formation (Transition Zone)	
Interbedded grey to dark grey shale and very fine brown sand	13·0
Shale, dark grey, with very fine light brown sand and silt beds	15·5
Siltstone layer, pale grey, hard	0·3
Bearpaw Formation	
Shale, dark grey, some friable, with a few thin layers of light brown silt	11·5

The Eastend is here only 18 feet thick. A mile and a half southeast, in the NE. ¼ sec. 34, tp. 2, rge. 25, is a similar section, as follows:

	Thickness Feet
Frenchman Formation	
Sandstone, greenish brown to brown, some grey, compacted, medium- to coarse-grained at base; occasional concretions; some thin, hard laminæ; rusty silty shale bed at base	114·0

Eastend Formation	Thickness Feet
Thinly bedded, yellowish buff, very fine sandstone; 2 feet above base is a lens of conglomerate in which are small pebbles of dark grey shale encrusted with iron	6·0
Bearpaw Formation (Transition Zone)	
Interbedded dark grey shale and very fine light buff sand and silt...	7·5
Silt, yellowish brown	0·7
Shale, dark grey to greenish grey, with beds of silt and light brown sand; limonite; coarse mica	7·0
Bearpaw Formation	
Light grey weathering dark grey to greenish grey shale with a few laminæ of silt and fine sand	12·8

The Eastend formation is here only 6 feet thick. Composite sections along the southwest side of Old Man On His Back Plateau indicate a total thickness for the Eastend formation there as between 50 and 60 feet.

In the southeast corner of sec. 22, tp. 6, rge. 24, on the north side of Frenchman River, the Frenchman formation cuts down into the Eastend formation as indicated in the following section:

Cypress Hills Formation	Thickness Feet
Conglomerate	11·0
Frenchman Formation	
Coarse, rich brown to greenish brown, clean sand	22·7
Eastend or Frenchman Formation (?)	
Shale, light battleship grey, hard	18·8
Limonite and rusty ironstone nodules	0·2
Eastend Formation	
Sand, very fine, brown	1·6
Interbedded grey shale and yellowish to buff, silty shale; 2-inch beds.	7·0
Shale, greenish brown	3·8
Concretions of hard, grey, fine sandstone in brown, very fine sand...	0·5
Sand, fine, brown	0·8
Shale, greenish grey, with thin beds of fine brown sand	1·6
Sand, brown, very fine; few thin laminæ of shale near base	9·4
Sand, greenish brown, argillaceous	0·5
Sand, very fine, grey	4·4
Sand, very fine, brown; some concretions	3·0
Sand, very fine, pale grey-buff; laminæ of dark brown organic material	5·6
Interbedded, greenish grey shale and fine buff sand	2·0
Sand, very fine, buff	1·1
Interbedded greenish brown shale and thin beds of very fine buff sand.	2·4
Sand, very fine, buff	0·6
Interbedded greenish grey to brown shale and thin beds of very fine buff sand	2·5
Sand, very fine, buff	1·3
Interbedded greenish brown shale and very fine buff sand; beds 6 inches thick	6·1
Sand, very fine, brown	1·8
Interbedded, greenish brown shale with a few thin beds of very fine buff sand	8·4
Bearpaw Formation	
Shale, brownish grey to greenish grey	12·2

It is difficult to place the base of the Eastend formation in this section. It is assumed that the transitional zone is represented essentially by the lower 16·3 feet above the typical Bearpaw shale, then there is 47·7 feet of definite Eastend strata. The rusty layer at the top of this section may here mark the unconformity with the overlying Frenchman formation, in which case the 18·8 feet of grey shale above it would represent locally reworked shale deposited as a result of river scouring during the period of erosion prior to deposition of the Frenchman coarse sands. On the other hand, McLearn (1930, pp. 51, 52; Fraser *et al.*, 1935, pp. 30, 31) has described dark shale at the top of the Eastend formation that bears local unconformable relations with the overlying white sand of the Whitemud formation. The shale could, therefore, represent uppermost beds of the Eastend.

Palæontology. Fossils are scarce in Eastend beds. Two poorly preserved specimens found in a coulée west of Pearson's quarry on the south side of Frenchman River, at the south boundary of sec. 22, tp. 6, rge. 23, were identified by McLearn as *Protocardia* sp. and *Dentalium* sp. These were collected 17 feet below the top of the formation.

A tooth found in beds near the top of the formation on the east side of Battle Creek, in the SE. ¼ sec. 21, tp. 7, rge. 29, was identified by C. M. Sternberg of the Geological Survey as that of a carnivorous dinosaur.

Russell and Landes (1940, p. 199) present a list of the fauna collected from the Eastend. However, as previously noted the three localities from which this fauna was collected all occur in the Belanger member of the Bearpaw formation and do not belong to the true Eastend.

Correlation. In the Cypress Lake area the Eastend formation can be traced fairly continuously to the type locality at Eastend, Saskatchewan, where it has been described and its correlation fully discussed (Fraser *et al.*, 1935, pp. 25, 26).

The Eastend formation has few fossils, and no short-ranging species have been established definitely in either the Eastend or the upper part of the Bearpaw formation, so that palæontological evidence is of only limited value in correlating these strata with similar strata south of the International Boundary. However, an approximate correlation can be made on the basis of lithology and stratigraphy.

The type locality of the original Fox Hills formation lies between Cheyenne and Moreau Rivers in South Dakota (Meek and Hayden, 1862). The correlation of the Eastend with this type section has been discussed (Fraser *et al.*, 1935, p. 26) as follows:

"In eastern Montana the Fox Hills consists of the Colgate and Lower or Brown sandstone members. If, as Thom and Dobbin (1924) and Dobbin and Reeside (1929) state, these two members are together equivalent to the Fox Hills of the type locality, and if the correlation of the Whitemud with the Colgate is correct, it follows that the Eastend is approximately the equivalent of the lower member of the Fox Hills of eastern Montana (Russell, 1933B)."

As will be shown subsequently, this means that only the Upper Sandstone member of Williams and Dyer's "Fox Hills" formation is a direct correlative of the Lower or Brown Sandstone member of the Fox Hills formation of eastern Montana, and, therefore, the Oxarart sandstone member of the Bearpaw, with its *Halymenites major* fossils, is some 200 feet lower in the stratigraphic section than the base of the true Fox Hills stratigraphic equivalents in this area, namely the Eastend and the Whitemud beds. The correlation of the Blood Reserve sandstone with the Oxarart member, as previously discussed, appears to be well

founded. The Blood Reserve sandstone must, therefore, likewise be older than the original Fox Hills. Russell (Russell and Landes, 1940, pp. 83, 84) previously arrived at this conclusion on the basis of stratigraphic and palæontological evidence from western and central Alberta, and the foregoing appears to confirm his observations in this respect.

The correlation of the Eastend of southern Saskatchewan with the Eastend of Alberta (*See* Figure 1) has been discussed (G. M. Furnival, 1941). Russell (1933, p. 132; 1940, p. 86) described the Eastend of Alberta as a much thicker formation than that in the type locality. This was based on the study of sections on the east side of Medicine Lodge Coulée, Alberta, and along Thelma Creek, below Thelma, Alberta.

Exposures along Thelma Creek consist of a series of outcrops extending from about $1\frac{1}{2}$ to 6 miles south of Thelma, Alberta. The section has been measured and studied by McConnell (1885), Williams and Dyer (1930), and Russell (1933 and 1940). As pointed out by Russell, there has been considerable discrepancy in the measurements assigned to this section, due largely to the fact that the outcrops are spread over a long distance, that the strata are slumped and tilted, and that overlap of successive sections is small. Russell's section is as follows:

	Thickness Feet	
Uppermost member: silt and fine sand, pale buff, transitional above to Whitemud beds............	30	
Carbonaceous member: alternation of sand and clay, with carbonaceous beds and at least one lignite seam...........................	49	
Upper sandstone member: sandstone, soft, massive, crossbedded, grey-buff or brown...	37	
		116
Shale member: shale, friable or fissile, grey-brown, sandy or bentonitic in places; some clayey sandstone..........................	95	
Lower sandstone member: sandstone, soft, massive, crossbedded, grey and grey-buff, finely banded with brown....................	172	
		267
Total thickness.................................		383

These are the beds that constitute the Lower Sandstone, the Shale, and the Upper Sandstone members of the Fox Hills formation as described by Williams and Dyer (1928), though the total thickness was given as 655 feet. Russell restudied this section, but was unable to satisfy himself as to the true thickness of the formation and, subsequently, measured a more dependable section, more than 324 feet thick, on the east side of Medicine Lodge Coulée (1940, p. 87), which extends from the Whitemud down to a massive sandstone that he correlated with the top of his Lower Sandstone member in the Thelma section. The present writer has studied these sections in detail and finds adequate lithological evidence for correlating the Lower Sandstone with the Oxarart member of the Bearpaw formation in the Cypress Lake map-area. Furthermore, the lithological succession between this member and the base of the Whitemud is quite similar to that at the west side of the map-area immediately east of the Alberta-Saskatchewan boundary.

In studying the exposures along the east side of Medicine Lodge Coulée, elevations were carried by plane-table and hand level. The complete section consists of a series of eight overlapping parts that together extend for one-third mile along the north side of a small east-west coulée in SE. $\frac{1}{4}$ sec. 7, and SW. $\frac{1}{4}$ sec. 8, tp. 7, rge. 3, W. 4th mer. The composite section is as follows:

	Thickness Feet
Frenchman Formation	
Sand, greenish brown, fine- to medium-grained, compacted, clean; limonitic layer 1 inch thick at base	1·5
Battle Formation	
Shale, dark brown to black, bentonitic	5·4
Shale, brownish grey, silty	0·9
Whitemud Formation	
No. 3 zone	
Clay, white weathering, pale grey, sandy	4·0
Interbedded fine yellow sands, pale yellowish grey clay, and yellowish brown silt with much limonite	2·6
Interbedded pale grey to white and cream-coloured clay, sandy clay, and very fine sand	4·0
No. 2 zone	
Shale, grey to dark grey, almost black	3·3
Clay, grey, with 2-inch yellowish layer near base	1·9
Shale, black, carbonaceous	0·5
Clay, medium grey	0·5
Concealed (some white clays and sands)	10·0
No. 1 zone	
Shale, cream, bentonitic	0·5
Bentonite, light green to olive-green	4·8
Sand, compacted, buff	2·3
Siltstone, hard, rusty	0·8
Clay, blue to greenish grey	1·0
Sand, white weathering, compacted, light grey, feldspathic, and micaceous, fine- to medium-grained	9·0
Eastend Formation	
Shale, dark blue to greenish grey to olive-green, bentonitic	7·6
Sand, very fine, buff; silt; grey shale; limonite laminæ	15·0
Concealed	3·0
Interbedded grey shale and yellowish brown to buff siltstone grading up into compacted, very fine, brownish grey sand and grey shale	6·3
Shale, black, carbonaceous	1·3
Lignite	2·9
Shale, purplish brown	0·5
Shale, light grey to dirty yellowish grey and pale greenish grey; yellow silts	10·0
Shale, dark grey to black	0·1
Shale, light grey	0·1
Sand, very fine (silt grade), finely bedded grey to brownish grey to greyish brown; laminæ of limonite	16·2
Shale, purplish grey, silty; organic material	3·5
Sand, very fine, compacted, grey; limonite laminæ	2·0
Interbedded, hard, grey, silty shale and yellow siltstone	2·5
Lignite	2·3
Shale, greenish grey, bentonitic	0·8
Shale, brown, organic, fissile, mottled with yellow spots	1·9
Siltstone ledge, laminated brown and light greenish grey, argillaceous	1·9
Shale, dark brown to black, fissile, organic, little lignite	1·7
Shale, dark grey, mottled with light greenish grey, silty shale; particles of organic material	0·7
Shale, dark brown, fissile, organic, hard	2·3
Lignite and brown organic material	3·0
Shale, hard, greenish brown, greasy	0·6
Lignite	1·2
Shale, hard, greenish brown, greasy	0·5
Shale, light brown, fissile, organic	0·5
Shale, dark brownish grey, hard, fissile; little organic material	0·8
Lignite	0·7
Sand, light grey, compacted to hard, very fine-grained; purplish brown for 0·5 foot at top	30·0
Sand, interbedded greyish brown and grey, very fine; a few thin shale laminæ	3·0

Bearpaw Formation	Thickness Feet
Interbedded dark brownish grey to grey shale and brown to brownish grey very fine sand; limonite	8·0
Shale, blue-grey weathering, dark greenish grey to dark grey; occasional brown silt layers; few small siltstone concretions	70·0
Lignite	2·2
Purplish brown, fissile, organic sandstone	0·4
Sand, compacted to hard, pale grey to white weathering, fine- to medium-grained, micaceous, feldspathic, light grey to brownish grey near base; thin laminæ of fissile dark brown shale; bedding 8 inches thick (Thelma member)	38·0
Interbedded shale and sand	0·4
Sand, light brownish grey, fine, compacted	1·0
Shale, dark grey	0·4
Bentonite, grey	0·1
Shale, dark grey	12·7
Interbedded brownish grey shale and brown, fine-grained sandstone; bedding 1 inch thick	5·0
Sand, fine, compacted, brown, with thin brown shale laminæ 6 to 8 inches apart (Belanger member)	4·5
Concretions, brown weathering, dark grey, fossiliferious, siltstone, 1 to 3 feet thick, at various levels in fine brown sand as above (Belanger member)	8·0
Sand, fine, compacted, brown, with thin brown shale laminæ as above (Belanger member)	12·0
Shale, dark grey, sandy, with beds of brownish grey to brown, compacted, fine sand	11·6
Shale, dark grey to dark brownish grey, at places silty to sandy; a few thin beds of fine brownish grey sand	11·0
Bentonite, greenish grey to yellowish grey	0·2
Shale, hard, dark brownish grey	2·0
Lignite (top of Oxarart member)	0·6
Dark brownish grey, fissile, organic shale mottled with yellow	0·9
Siltstone layer, shaly, pale greenish weathering, rusty coated	0·6
Shale, dark brownish grey, fairly fissile	1·2
Sand, hard, greenish grey, weathering rusty, coated grey with particles of organic material	0·7
Shale, dark brown, fissile	0·8
Sand, purplish brown, compacted with fragments of organic material.	6·0
Sand, greenish grey to grey, fine- to medium-grained, compacted to hard; mica along bedding planes; glauconite	30·0
Sand, compacted, brownish grey	1·3
Brown organic shale and brown sand	0·5
Sand, brown, compacted, fine	13·0

The thick grey sandstone, the compacted brown sandstone, and the lignitic beds comprising the lower 55·6 feet of the above section represent the top of the Oxarart member of the Bearpaw. The Eastend formation is here indicated to be 122 feet thick. Like the Eastend at the type locality the sands are very fine-grained and at places almost of silt grade.

A second section was measured on the east side of Medicine Lodge Coulée, in the SE. ¼ sec. 31, tp. 7, rge. 7, rge. 3, W. 4th mer., just northeast of a small schoolhouse, as follows:

Frenchman Formation	Thickness Feet
Sandstone, greenish brown, compacted, fine- to medium-grained.	
Whitemud Formation	
No. 3 zone	
Interbedded pale grey and yellowish grey clay	3·1
No. 2 zone	
Shale, dark brown to black	1·2
Sand, fine, pale grey; light grey shale near base	1·9
Shale, brownish grey to light brownish grey	4·8

Whitemud Formation—Concluded

No. 2 zone—*Concluded*	Thickness Feet
Black carbonaceous shale and lignite	0·5
Shale, dark brownish green	1·0
Interbedded greenish grey shale and light brown shale	0·3
Sand, white weathering, light grey, very fine	3·8
Shale, white weathering, light grey and greenish grey	2·0
Bentonite, olive-green	2·0
Sand, white weathering, pale grey, some silt	3·0
Eastend Formation	
Shale, grey weathering, greenish grey to olive-green, and pale brownish grey silt	24·0
Interbedded, brownish grey to grey sands, silts, and grey shale; dark grey shale zone at top	4·0
Siltstone concretions, buff weathering, purplish brown	0·5
Sand, compacted, very fine, buff	4·0
Sand, grey and brownish grey, very fine; grey shale; yellowish brown siltstone laminæ with limonite	11·5
Shale, dark grey to black	0·7
Shale, brown, organic, fissile	1·5
Lignite	1·5
Shale, greenish grey, bentonitic	3·0
Interbedded grey to buff, very fine sand and grey shale; yellow silt laminæ	7·0
Shale, greenish grey; becomes black and brown at top	4·2
Sand, very fine-grained, pale grey; laminæ of grey shale and limonite	2·0
Sand, compacted, fine-grained, crossbedded, light grey to buff; brown limonitic laminæ	17·0
Lignite (mined out, thickness estimated)	2·0+
Siltstone laminated layers, greenish grey, with interbedded dark grey shale	2·0

A few hundred feet south of the preceding section is the following section, which overlaps the lower part of the other:

Eastend Formation	Thickness Feet
Sand, compacted, grey to yellowish brown, very fine, crossbedded	2·0+
Lignite	0·5
Shale, dark grey and greenish grey	7·3
Shale, dark grey, grading up to black	4·0
Sand, grey, with thin beds of grey shale and yellow silt	6·0
Shale, green to greenish grey, dark at top	1·2
Shale, brown, organic, fissile	2·5
Lignite	3·0
Shale, dark grey; grey silt; many fragments of organic material	2·7
Siltstone, hard laminated layer, buff and greenish grey; little sand; many particles of brown, organic material	2·0
Shale, brown, organic, fissile	1·1
Shale, green, bentonitic; limonite	0·2
Shale, silty, hard, greenish grey, with particles of brown, organic material, and nodules of dark grey siltstone	1·2
Shale, black and brown, fissile, organic, with laminæ of lignite	8·5
Sand, compacted, greenish grey grading up to brown	1·4
Sand, grey to greenish grey, compacted to hard, fine	15·0
Concealed	17·0
Bearpaw Formation	
Concealed; appears to be in large part shale	96·5
Sandstone, hard, light grey, fine- to medium-grained; rusty coated at top (Thelma member)	8·5
Sand, compacted to hard, fine-grained, brown, brownish grey, and grey, with thin laminæ of brown shale (Thelma member)	36·6
Shale, dark brownish grey to dark grey, with beds of fine brown sand	22·4
Sand, compacted, fine-grained, brown; shale laminæ (Belanger member)	12·2

Bearpaw Formation—Concluded	Thickness Feet
Concretionary layer, brown to buff weathering, dark grey siltstone; highly fossiliferous (Belanger member)	1·5
Sand, brown, fine-grained, with thin laminæ of dark brown shale (Belanger member)	1·8
Interbedded, dark brown, sandy shale and brown sand (Belanger member)	13·0
Shale, dark brown, thin laminæ of brown sand	5·0
Concealed	17·5
Sandstone, hard, medium-grained, rusty coated, grey to greenish grey, crossbedded at places; white fossilized wood; casts of burrowings (top of Oxarart member)	47·0

Allowing for overlap in these two sections and a small amount of slumping in the lignite-bearing zone of the second section, the exposed thickness of the Eastend formation is 100 feet. However, the previous section shows that the grey sand at the base of the Eastend below the lowest lignite bed is 33 feet thick. In this section 16·4 feet of sand is exposed below the lower lignite bed; therefore, the contact with the underlying Bearpaw formation may be assumed to be about 17 feet below this, and the total thickness of the Eastend becomes approximately 116 feet.

There is a considerable variation in thickness and lithological succession in the lignite-bearing zone as measured in the above sections. It was first thought this was due to local slumping and downhill creep of the beds. However, the interval from the base of the top lignite layer, below the thick section of fine buff and grey sand, to the top of the main, lower lignite beds is, respectively, 31·9, 33·2, and 31·2 feet in the three sections. It appears, therefore, that the variation is due largely to the lenticular character of the lignite beds.

The top of the Eastend formation does not appear to be at the same horizon in the above sections. The vertical interval from the base of the olive-green bentonite in the No. 1 zone of the Whitemud formation to the base of the uppermost lignite bed in the Eastend formation in the first of these three sections is 49·2 feet. The same interval in the second section is 50·7 feet. Yet the base of the Whitemud formation in the first section is 17·9 feet below the top of the olive-green bentonite, whereas in the second section it is only 5·0 feet below the bentonite. This may be due to local scouring during deposition of the basal beds of the Whitemud. A similar condition was found farther east in Saskatchewan (McLearn, 1930, pp. 51, 52; Fraser *et al.*, 1935, pp. 30, 31).

The base of the Eastend formation is drawn at the top of the 80- to 90-foot section of shale. This shale constitutes part of the "Shale member" of Russell's Eastend and of the former Fox Hills, and it was recognized by even the early workers that the shale was of marine origin. Wickenden has more recently identified marine foraminifera from these beds. Glauconite is common in the Belanger member and other sands in the shale beds lower in the section. Russell and Landes collected their entire Eastend marine fauna from three fossil localities in the sections measured on the east side of Medicine Lodge Coulée, Alberta. In all three places the fossiliferous horizon proved to be the concretionary layer in beds now regarded, for reasons already stated, as those of the Belanger member of the Bearpaw formation. Consequently, the writer believes that, unless the term "Eastend" is to lose its original definition and meaning, it should be restricted to the upper sand and lignite beds as indicated in the two sections just detailed. In these sections, therefore, it would have an approximate thickness of 120 feet. In Russell's section at Thelma it would seem to correspond to the three top members, namely, the Uppermost, the Carbonaceous, and the Uppermost sandstone members. There is no faunal evidence for including the Shale member and the Lower Sandstone member with the Eastend formation. On the contrary, Landes, in discussing the fossils identified from the Shale

member, states that they are of a type more characteristic of the latest Pierre than of the typical Fox Hills. Lithologic, stratigraphic, and faunal evidence all support the view that the base of the Eastend formation should be drawn at the top of the large section of marine shale in these exposures.

The three sandstone members in the Bearpaw here are undoubtedly the correlatives of the Oxarart, the Belanger, and the Thelma members, respectively, in the Cypress Lake map-area.

In order to complete a study of the entire section included in Russell's "Eastend" the section at Thelma was examined. Time did not permit a detailed measurement of all this section. The Whitemud-Eastend contact, however, was studied, and the section across this contact is as follows:

Whitemud Formation	Thickness Feet
Interbedded, white weathering, white and yellow clays.	
Sand, compacted, white weathering, light grey, fine-grained	5·0
Eastend Formation	
Interbedded grey shale, buff silt, and beds of brown to buff, very fine, compacted sand 2 feet thick	12·0
Sand, compacted to hard, yellowish brown, very fine-grained; limonitic laminæ	16·0
Shale, dark grey, fissile	2·0
Lignite; two shale partings	8·0
Sand, hard, grey, fine	5·0
Interbedded grey shale and sand	5·0
Sand, hard to compacted, grey	12·0
Concealed.	

Outcrops lying between the foregoing section and those containing the beds described below were not examined. The lower part of the section is as follows:

Bearpaw Formation	Thickness Feet
Concealed.	
Shale, dark grey; sandy at base	6·0
Bentonite, yellowish green	0·2
Lignite (top of Thelma member)	0·2
Bentonite, reddish brown	0·1
Sand, brown, organic	0·5
Sand, compacted to hard, brownish grey at base grading up to grey, crossbedded; shale and limonitic laminæ (Thelma member)	40·0
Interbedded dark brown shale and brown and grey fine sand	12·0
Shale, dark grey with brownish grey sand at top	16·0
Bentonite, greenish grey	0·8
Shale, dark brownish grey; some brown sand near base	8·0
Sand, argillaceous, compacted, buff-grey; mottled shale and fine sand; small fossiliferous concretions, 1 foot across in middle of zone (Belanger member)	15·0
Shale, sandy, dark grey	25·0
Sand, hard, greenish grey, rusty coated, much white and brown, fossilized wood; casts of burrowings and plant impression (Oxarart member)	3·0
Sand, compacted, brown to brownish grey, horizontally bedded and crossbedded; thin brown shale and limonitic silt laminæ (Oxarart member)	112·0
Interbedded dark grey to brownish grey shale and greyish brown to brown, fine-grained sand	27·5
Shale, dark grey	70·0

The Oxarart member is here 115 feet thick, or, if the interbedded zone at the base is included, 143 feet. The Belanger member is more greenish grey and silty than the typical brown sand comprising the member in the Cypress Lake

area, but resembles the greenish grey sandstone "fragments" found in the member there. The Thelma sandstone is well exposed, and there seems little doubt that it has been responsible for much of the confusion in measuring the sections in this part of the Cypress Hills. It resembles in general appearance the 33-foot grey sandstone at the base of the Eastend formation, and like it is overlain by lignite, though only a thin bed, but sufficient to cause some of the workers to believe the two sands represented the same stratigraphic horizon. The presence of a third sandstone member in the upper part of the Bearpaw was first recognized in the sections on Battle Creek, Saskatchewan, where it occurs 90 feet below the Bearpaw-Eastend contact.

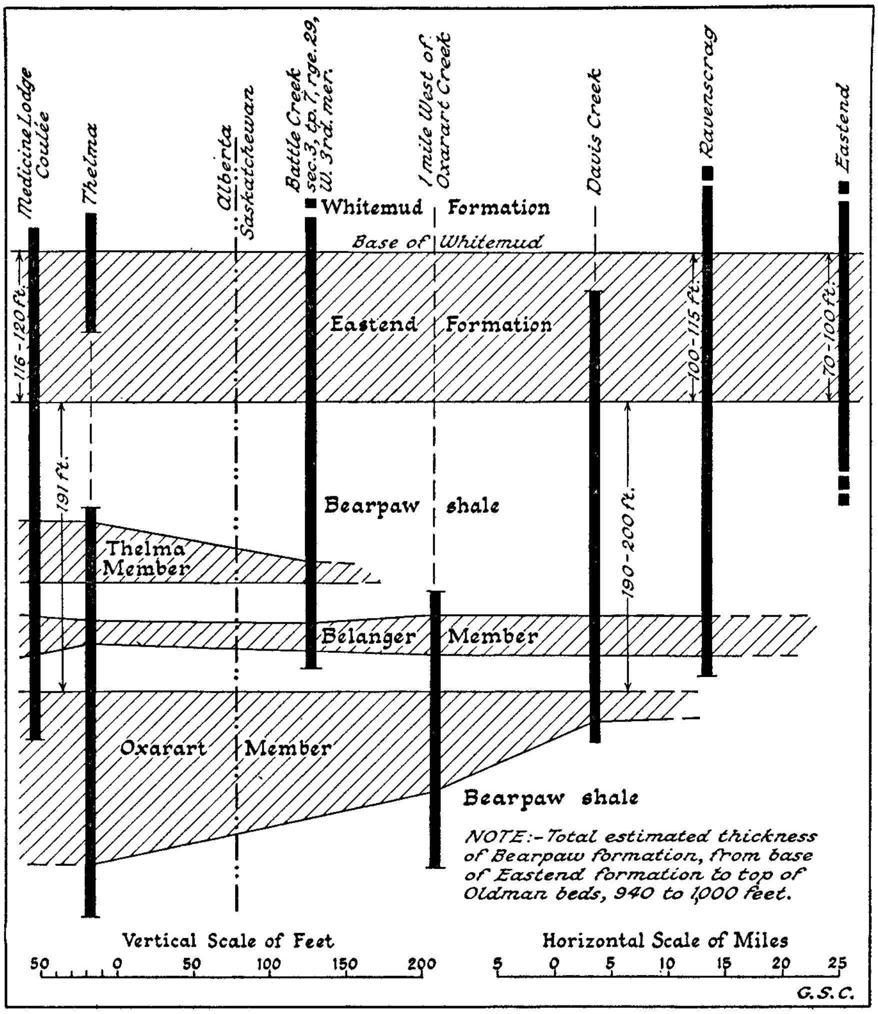


Figure 1. Diagram illustrating correlation of Upper Bearpaw and Eastend beds from Eastend, Saskatchewan, across Cypress Lake map-area to Medicine Lodge Coulée, Alberta. Base of Whitemud formation used as a datum plane.

Figure 1 illustrates the stratigraphy and correlation of the formations along the south slopes of the Cypress Hills from Eastend, Saskatchewan, to Medicine Lodge Coulée, in Alberta.

The correlation of the Eastend beds with beds exposed on the west side of the Sweetgrass arch cannot be made with any degree of certainty or accuracy in the absence of definite palæontologic evidence. However, certain relations based upon lithology and stratigraphy are worthy of consideration.

The fauna of the St. Mary River beds in Alberta, as reported by Russell, though indicating brackish water conditions near the base, is largely a fresh-water and land fauna in the upper part. The change in conditions of sedimentation there is similar to that which occurred throughout the deposition of the Eastend beds. Lignite and carbonaceous shale beds occur throughout the St. Mary River beds as well as in the Eastend.

The St. Mary River formation is best exposed along Oldman River northwest of Monarch, Alberta, and along St. Mary River west of Magrath, Alberta. These beds have been studied by various investigators. Williams and Dyer (1930, p. 54), though recognizing that some folding has occurred, estimate that the formation has a thickness of 1,600 feet at both the exposures referred to above. On Oldman River, Russell (Russell and Landes, 1940, pp. 85, 86) estimates a thickness of 1,500 feet. The writer had an opportunity to study this section as well as those along St. Mary River. A study of the dips in the beds exposed along Oldman River northwest of Monarch shows that the section has a greatly increased apparent thickness due to minor thrust faulting. It would appear not only that the above reported thicknesses are excessive, but that it is not possible, from a study of the surface exposures alone along the Oldman, to make more than a rough estimate of the true thickness of the formation. Using graphic methods a figure of approximately 1,000 feet is arrived at. Though the beds along St. Mary River are folded, these are relatively broad flexures, and, unlike the Oldman exposure, the beds here show little evidence of faulting. A careful study of the exposures here, plus subsurface data from adjacent deep wells, indicated a thickness of approximately 900 feet. This figure would seem to be supported by Stebinger's observations (1914, pp. 330-2). He measured a section of the St. Mary River formation along Little Rocky Coulée, tp. 35N, rge. 9W, and tp. 36N, rge. 10W, in Montana. These exposures are approximately 8 to 20 miles due south of Del Bonita, Alberta, and some 35 miles south of the section measured along St. Mary River. Stebinger found the total thickness of the formation was here 990 feet. It is underlain by the Horsethief sandstone, the equivalent of the Blood Reserve sandstone of Alberta, and overlain by the Willow Creek formation. A thickness of about 900 to 1,000 feet may be assumed for the St. Mary River beds.

The probable correlation of the Oxarart member of the Bearpaw and the Blood Reserve sandstone has been discussed on previous pages. If it be accepted that the surfaces of these sandstone units are approximately at the same stratigraphic horizon, then at least the lower 200 feet of the St. Mary River would appear to be the equivalent of the upper 200 feet of Bearpaw beds lying above the Oxarart member and below the Eastend beds as used in the restricted sense. Some part of the remaining 700 to 800 feet of St. Mary River beds would then be the equivalent of the Eastend beds, which are 120 feet thick at Medicine Lodge Coulée, 120 miles east.

WHITEMUD FORMATION

The Whitemud formation consists of a group of white weathering, kaolinized, feldspathic sandstones, clays, and silts that overlie the Eastend formation and form a prominent horizon marker over a large part of southern Saskatchewan and southeastern Alberta. The formation is particularly well exposed along the valley of Frenchman River and its type locality is near Whitemud post office,

Saskatchewan. Though observed by McConnell in 1885, it was first given a formational name by N. B. Davis in 1918.

A comprehensive study of the stratigraphy and origin of the Whitemud was made by McLearn and others (Dyer, 1927; McLearn, 1928 to 1931, 1935; Fraser *et al.*, 1935, pp. 26-39). As a result, the formation was divided into four zones: Nos. 1 and 3 consisting essentially of white weathering, partly kaolinized, refractory or partly refractory beds; No. 2 zone containing much brown and black organic material; and the uppermost or No. 4 zone consisting of non-refractory, dark brownish grey to almost black, bentonitic clay and greenish grey clays, silts, and shales (Dyer, 1927, p. 33; McLearn, 1928, p. 27). For reasons that will be discussed, the No. 4 zone, comprising the black bentonitic clay and the overlying greenish grey silts and shales, is named the Battle formation in this report. The term "Whitemud" is, therefore, restricted to the white weathering, mainly refractory beds constituting the Nos. 1, 2, and 3 zones. In general, this subdivision applies equally well in the Cypress Lake map-area, although at places the No. 2 zone may include two or three groups of distinct, dark, carbonaceous beds.

Within the map-area the No. 1 zone is generally a thick, fairly massive, medium- to coarse-grained, partly kaolinized, feldspathic, compacted sandstone. At the top it grades into finer sand, purplish in colour due to organic material. Some white and yellow silt and shale may be interbedded, particularly near the top. It is commonly crossbedded, the foreset beds of which dip east, northeast, southeast, north, and south, but nowhere were observed dipping west. Occasional laminæ of purplish brown organic material are present. White mica is common. Limonite laminæ and nodules, common along Battle Creek and other places, have resulted in an irregular brownish coloration in the sands. Where tested by McLearn, the beds of this zone were found to be in part refractory.

The No. 1 zone varies in thickness from 33 feet to 45 feet, but appears to average about 35 feet. The basal contact with the underlying Eastend formation is quite irregular in detail, due to local erosion. McLearn observed similar evidence of local erosion at this contact in exposures in southern Saskatchewan east of the Cypress Lake map-area (1935, pp. 30, 31). At many places, however, the contact is transitional across a few feet into typical fine brown sand of the Eastend formation.

The No. 2 zone consists of one or more bands of brown and black, organic and carbonaceous shale with or without beds of lignite (*See* Plate III A). At places the lignite forms seams $1\frac{1}{2}$ feet thick, but more commonly 6 inches or less. Between the lignite seams and carbonaceous beds are beds of kaolinized, feldspathic, fine- to coarse-grained, light grey to white clay and shale. Fossil tap roots are common in these beds. The carbonaceous beds are either lenticular or form a network of anastomosing layers of organic material. The dark-coloured organic zones are composed of coarse, non-refractory material, but some of the intervening beds may well be refractory. The thickness of the No. 2 zone varies with each exposure and ranges from less than 1 foot to 22 feet.

The No. 3 zone (*See* Plate II B) consists of a series of interbedded, grey to white, pale green, pale blue, and yellow, plastic to hard clay and shale, light grey to white, kaolinized, feldspathic, fine sand, and yellow silt. The bedding is generally fine, though the clays at places may be thick and massive. Some clays show a fine colour banding. As with the No. 2 zone, there is considerable lateral variation, and it is difficult to correlate individual beds from place to place. Fossil tap roots are common. Samples of these beds taken by McLearn east of the map-area proved to be refractory, with the most refractory beds commonly at the top. The thickness of this zone, like that of No. 2 zone, is variable from

place to place. Though the combined thickness of the No. 2 and the No. 3 zones, in those areas where the latter is overlain by the Battle formation, ranges from 16·4 to 46·5 feet, it is commonly 30 to 36 feet.

The total thickness of the Whitemud formation within the map-area, where it is in contact with the Eastend formation below and the Battle formation above, ranges from 60 to 75 feet. In part, this variation may be the result of local erosion. However, exposures of the formation on the north side of Frenchman River, 2½ miles west of Ravenscrag, indicate that the No. 2 and No. 3 zones have a combined thickness of only 16 or 17 feet and that there is no increase in the thickness of the No. 1 zone, so that here the formation is only 50 feet thick. This abnormally thin section for the entire Whitemud appears to be quite a local condition.

The Whitemud formation is not everywhere in contact with the overlying Battle formation, but, like the Eastend formation, has been subjected to erosion prior to deposition of the post-Battle, Frenchman formation. At many places within the area Whitemud beds are in contact with the coarse, greenish brown sands of the Frenchman formation, erosion having removed all of the Battle formation and more or less of the Whitemud (*See* Plate III B). At other places erosion has also removed all of the Whitemud and part of the underlying Eastend formation. This is so along the south side of Old Man On His Back Plateau, where only small sections of the No. 1 zone of the Whitemud occur between the Eastend and Frenchman formations, and where the Frenchman elsewhere is in contact with the Eastend formation. Sections showing the latter condition have already been given. Further evidence of this erosional unconformity is seen in outcrops on the north side of Frenchman River Valley, in the SW. ¼ sec. 25, tp. 6, rge. 24. Here the Frenchman formation is in direct contact with the No. 1 zone of the Whitemud, and the same is true in the NE. ¼ sec. 31, tp. 6, rge. 23, due north of Ravenscrag. On the west side of Table Butte, in sec. 10, tp. 6, rge. 24, the Frenchman formation is in direct contact with the lower beds of the Whitemud formation.

During a subsequent erosional period that preceded the deposition of the Cypress Hills formation, beds as low as the Bearpaw formation were removed in places. In some parts of the map-area the Whitemud beds still remaining after the pre-Frenchman erosional period, were later removed prior to the deposition of the Cypress Hills beds. The Cypress Hills formation can be seen resting directly upon the lower beds of the Whitemud formation on the west side of Table Butte, in sec. 10, tp. 6, rge. 24, and along the north side of Frenchman River Valley, in secs. 22 and 26, tp. 6, rge. 24. These relations are illustrated in Figure 2.

Distribution. The Whitemud formation is well exposed along both sides of Frenchman River Valley from the east boundary of the map-area to the middle of rge. 24, along the valley of Adams Creek in the SW. ¼, tp. 7, rge. 28; and along the valley of Battle Creek in tp. 7, rge. 29, and tp. 8, rge. 30. Limited exposures occur along the south side of Old Man On His Back Plateau, and on the west side of Boundary Plateau. A small outcrop appears in sec. 29, tp. 6, rge. 30. Though the Whitemud outcrops along the north slopes of the Cypress Hills immediately west of the map-area, in Alberta, only one small exposure was found on these northern slopes within the Cypress Lake area, in sec. 26, tp. 9, rge. 25.

Detailed Description. The best exposures of the Whitemud formation in the map-area are along Frenchman River in the vicinity of Ravenscrag; along Adams Creek, in rge. 28; and along Battle Creek, in rge. 29.

The section on Ravenscrag Butte, in sec. 27, tp. 6, rge. 23, is as follows:

	Thickness Feet
Battle Formation	
Black, bentonitic shale.	
Whitemud Formation	
No. 3 zone	
Clay, light grey to grey, plastic	7·7
Shale, grey to dark grey, with much black organic material	2·5
Shale, grey; tap roots abundant	3·0
Shale, friable, pale green to white, finely banded; numerous fossil tap roots	1·0
Shale, dark grey	0·5
No. 2 zone	
Shale, black, carbonaceous	0·5
Clay, light grey and dark grey	3·4
Sand, fine, kaolinized, feldspathic, pale grey	9·0
Shale, light grey to white, friable	0·3
Clay, dark grey	0·5
Shale, black, carbonaceous, lustrous	1·0
Clay, purplish brown	0·5
No. 1 zone	
Shale, light grey; sharp contact with underlying sand	1·8
Sand, compacted, light grey, kaolinized, feldspathic, crossbedded, coarse; several laminæ of purplish brown, organic material	36·9
Concealed	2·0
Eastend Formation	
Total thickness	70·6

An exposure a mile east of the above, in sec. 26, tp. 6, rge. 23, was measured as follows:

	Thickness Feet
Battle Formation	
Dark grey to black shale.	
Whitemud Formation	
No. 3 zone	
Clay, light grey, white weathering (estimated)	23·2
Clay, pale grey, dark grey, and yellow, very slightly sandy	6·5
No. 2 zone	
Brown organic shale and lignite	0·5
No. 1 zone	
Sand, brown, medium-grained	2·0
Sand, coarse, massive, light grey, kaolinized, feldspathic; laminæ of brown organic material	41·6
Sand as above with fragments of the underlying shale, 2 inches across.	1·0
Eastend Formation	
Shale, medium grey; $\frac{1}{4}$-inch layer of limonite at top	2·3
Sand, very fine, brown	6·0

The Whitemud is here 74·8 feet thick. There is evidence of local erosion or scouring at the base of the No. 1 zone. Its contact with the underlying shale is irregular, and the presence of the limonitic layer at the top of the shale, and of fragments of the shale in the basal beds of the coarse white sand of the Whitemud, seem conclusive evidence of erosion.

A few hundred feet west of the above section is the following section:

	Thickness Feet
Battle Formation	
Shale, dark grey to black.	
Whitemud Formation	
No. 3 zone	
Clay, greenish grey, dark grey, and medium grey; at places hard....	8·5
No. 2 zone	
Shale, carbonaceous, dark grey..................................	0·5
No. 1 zone	
Clay, pale green, hard to friable................................	5·0
Clay, light grey to white...	9·6
Sand, white weathering, light grey...............................	0·5
Clay, white weathering, light grey to white.......................	5·5
Interbedded white clay and pale grey, fine sand; sharp contact at base.	1·0
Sand, white weathering, pale grey, coarse.........................	3·0
Sand, grey, with laminæ of black carbonaceous material............	1·6
Sand, white weathering, pale grey, coarse, kaolinized, feldspathic....	18·4
(Base not exposed)	

In sec. 22, tp. 6, rge. 24, 2 miles west of Ravenscrag and on the north side of Frenchman River Valley, is the following section:

	Thickness Feet
Battle Formation	
Dark grey to black shale.	
Whitemud Formation	
No. 3 zone	
Clay, medium grey, plastic....................................	4·6
Shale, dark grey, with thin laminæ of carbonaceous material........	1·6
Sand, pale grey to white, medium-grained, silty at top.............	4·6
Clay, pale grey and pale bluish grey; limonite laminæ at top........	1·8
Clay, pale brownish grey; silt.................................	1·0
No. 2 zone	
Lignite..	0·5
Shale, purplish brown, pale; some organic material................	1·6
Lignite and brown organic shale................................	0·7
No. 1 zone	
Sand, light grey to white, medium-grained, kaolinized, feldspathic..	28·0
Sand, light buff, fine, becoming more micaceous and paler near top; transition to Eastend....................................	5·6
Total thickness................................	50·0
Eastend Formation	
Shale, pale grey, soft, brownish grey near base....................	5·6
Sand, very fine, buff, and interbedded grey clay passing downwards into very fine, buff and grey sand..............................	40·4

A typical section on the south side of Frenchman River Valley, opposite that given above, is as follows:

	Thickness Feet
Battle Formation	
Dark grey to black shale.	
Whitemud Formation	
No. 3 zone	
Clay, medium grey..	4·1
Clay, light grey to white; particles of black organic material........	2·8
Shale, dark grey...	2·8
Clay, hard, white, dense subconchoidal fracture; little silt..........	8·4
Shale, dark grey...	0·9

Whitemud Formation—Concluded

No. 2 zone	Thickness Feet
Shale, black, carbonaceous; lignite	1·5
Shale, dark purplish brown, organic	0·5
Sand, massive to finely bedded at top, medium- to fine-grained, pale grey; fossil tap roots numerous	3·3
Shale, finely banded, light and dark grey	0·2
Lignite and black carbonaceous shale	0·7
Shale, dark brown grading up into black carbonaceous at top	3·3
No. 1 zone	
Sand, medium to coarse, pale grey to white, with round sandstone concretions	0·8
Shale, dark brown to purplish, fissile, with several thin lignite laminæ.	0·9
Shale, grey, interbedded with sand and thin laminæ of brown organic material	2·6
Interbedded light grey sand, yellow silt, and laminæ of brown organic material	1·0
Sand, light grey, medium to coarse, crossbedded, kaolinized, feldspathic, with occasional laminæ of brown organic material and grey shale; mica	27·5
Eastend Formation	
Shale, yellowish brown to grey at top	4·4
Sand, grey, very fine, interbedded with brown shale	3·5

The Whitemud here is 61·3 feet thick. The position of the No. 2 zone relative to the top and bottom of the formation is far from constant, and differs greatly in character from place to place. As many as three carbonaceous bands are present in places, as indicated by the following section from NE. ¼ sec. 20, tp. 6, rge. 23:

Battle Formation	Thickness Feet
Dark grey to black shale.	
Whitemud Formation	
No. 3 zone	
Clay, medium grey, plastic	6·0
Clay, pale grey to white to greenish grey; tap roots	5·6
Clay, medium grey	3·2
Clay, hard, pale grey to white	3·0
Sand, hard, pale grey to white, coarse, kaolinized, feldspathic	5·0
No. 2 zone	
Shale, dark grey	0·8
Shale, black	0·2
Shale, dark grey	0·5
Interbedded grey shale and pale buff to light grey, fine sand	5·8
Sand, pale grey, coarse, kaolinized, feldspathic	3·0
Shale, light grey	0·5
No. 2 zone	
Shale, light brownish grey	1·1
Shale, dark brown and black, carbonaceous; lignite	3·9
Shale, pale grey	2·3
Lignite and black shale	1·3
Shale, grey	0·1
Shale, dark brown, much brown organic matter	0·7
Shale, brownish grey, fissile, much brown organic matter	3·5
No. 1 zone	
Sand, coarse, pale grey, kaolinized, feldspathic	3·0
(Base not exposed)	

Numerous exposures of the Whitemud formation occur along Adams Creek near Spangler's ranch. A composite section of the exposures, most of which are in sec. 8, tp. 7, rge. 28, is as follows:

	Thickness Feet
Battle Formation	
Dark grey to black shale.	
Whitemud Formation	
No. 3 zone	
Clay, pale greenish grey to white; tap roots	2·0
Clay, pale greenish to yellowish grey and yellowish silts; fossil tap roots	1·0
Sand, white, clayey, fine	3·0
Interbedded, light grey, fine sand, yellow silt, and light grey clay; fossil tap roots	3·0
Sand, light grey, fine-grained, kaolinized; silt	9·0
Shale, yellow and silty	1·7
Clay, yellow, silty, interbedded with grey clay	0·8
Interbedded dark brownish grey to brown clay and yellow-brown clay.	2·0
Clay, dark brownish grey	1·0
Clay, yellowish brown	1·0
Concealed	7·0
Sand, pale cream to white, very fine	3·5
No. 2 zone	
Shale, bright yellow to brown, with interbedded yellow silts and dark brownish grey clay	2·5
Shale, pale greenish grey to light grey, silty; upper 2 inches brown	2·6
Shale, dark purplish brown and brown organic	0·3
Lignite, dull, hard, black	0·7
Lignite, shiny, hard, black	0·8
No. 1 zone	
Clay, pale greenish grey	0·2
Sand, medium- to coarse-grained, light grey to white, kaolinized, feldspathic, compacted to hard; mica common; limonite laminæ numerous near base	28·8
Brownish grey organic shale	0·1
Sand, light grey to white, kaolinized, feldspathic, fine-grained, becoming coarse at top; limonitic stained beds; coarse mica at top	4·5
Eastend Formation	
Sand, massive, very fine, greenish brown, compacted to hard; few limonite stained laminæ near top	12·0

Local scour and filling have occurred at the basal contact of the Whitemud in the above section. A dyke-like, downward-tapering extension of the white, kaolinized sand extends 6 inches into the pale greenish brown, very fine Eastend sand. An 8-inch bed of the greenish brown, very fine sand occurs in the lower 4·5-foot band of white, kaolinized sand. The Whitemud is here 75·5 feet thick. This is more than its usual thickness and may be due to some overlap in the composite section.

Numerous exposures of the Whitemud occur along the valley of Battle Creek in ranges 29 and 30, but nowhere was the lower contact with the Eastend formation observed. The total thickness here can, therefore, only be estimated.

The upper part of the formation is exposed in sec. 4, tp. 7, rge. 29, on the west side of Battle Creek, as follows:

Battle Formation	Thickness Feet
Dark brownish grey to black, bentonitic shale.	
Whitemud Formation	
No. 3 zone	
Interbedded, light grey, silty clay, pale bluish grey clay, and pale yellowish grey clay	15·3
Interbedded, fine, light grey, kaolinized sand, yellow silt, and pale yellow-grey clay	6·5
Clay, pale bluish grey	0·5
No. 2 zone	
Shale, dark grey	0·5
Clay, pale bluish grey	0·5
Shale, brown and black, organic; lignite	2·3
No. 1 zone (?)	
Sand, light grey to white, kaolinized, feldspathic, fine-grained	2·0

The sand at the base of this section may be the top of the No. 1 zone, or an intermediate bed between two carbonaceous zones.

An exposure of the central part of the formation occurs in sec. 29, tp. 7, rge. 29, on the east side of Battle Creek Valley. The section is as follows:

No. 3 zone	Thickness Feet
Interbedded, white, fine sands, silts, and pale brownish grey to white shale	10·0
Shale, pale brownish grey to dark brownish grey	0·8
No. 2 zone	
Purplish brown, organic shale; yellowish brown siltstone layer at top 2 inches thick	0·7
Clay, pale greenish grey	2·5
Clay, greenish grey, grading up into pale grey	4·0
Shale, grey and dark grey to black, sandy	1·7
Sand, fine- to medium-grained, pale grey to white, grading up into pale grey, silty shale	10·8
Shale, pale grey; limonite layer at top	1·3
Shale, black, carbonaceous; lignite	0·9
Sand, dark purplish brown, compacted	0·5
No. 1 zone	
Sand, fine, white, kaolinized, feldspathic	0·2
Limonite and limonitic nodules	0·05
Sand, pale brownish grey to light brown, fine- to medium-grained; limonite layers	10·0

The sand comprising the No. 1 zone in this exposure and a number of other outcrops in the vicinity is in part light brown and in part light grey to white with no well-defined boundaries, at first thought to be another sand below the Whitemud. Examination of other outcrops disclosed the origin of the brown sand. It was found to be closely associated with and to occur directly below limonite layers. The colour fades with distance from the limonite. In an outcrop $\frac{1}{4}$ mile northwest of the above section 15·0 feet of the No. 1 zone is exposed. The sand is generally pale grey to white, kaolinized, feldspathic, compacted to hard, and massive. Two inches below the top is a limonitic nodular layer, below which for a distance of a foot is brown-coloured sand. The colour fades gradually and irregularly out into light grey, and appears to be due to very late diffusion of the hydrous iron oxides from the limonitic layer. Elsewhere, and lower in the sand, are occasional small nodules of limonite.

Surrounding these are haloes of brown-coloured sand that pass gradually into the white or light grey sand. Some of the limonite nodules in these outcrops are iron-rich shells surrounded by haloes of the brown sand, but were found to be filled with the white, kaolinized, feldspathic sand. This seems conclusive proof that the brown sand was originally the white, kaolinized, feldspathic sand, and that subsequently, possibly due to weathering processes, hydrated iron oxide diffused irregularly through it from the iron-rich nodules.

It is difficult to estimate the total thickness of the Whitemud formation here, particularly as there are as many as three dark-coloured organic layers. However, only one of these, the lowest, appears to carry an appreciable quantity of lignite. The vertical distance from the base of this main carbonaceous zone to the top of the formation is 27·6 feet in the first section given above, from sec. 4, tp. 7, rge. 29, on the west side of Battle Creek, and 33·2 feet in the second section, about 3 miles farther north on the east side of Battle Creek in sec. 29, tp. 7, rge. 29. The top is not exposed at the latter section. The greatest thickness of the No. 1 zone exposed in this vicinity is 24 feet, in the NW. ¼ sec. 31, tp. 6, rge. 29. However, all previous sections of the No. 1 zone measured 33 feet and more. In Grayburn Gap, in the SW. ¼ sec. 24, tp. 8, rge. 1, W. 4th mer., Alberta, there is 33·8 feet of medium-grained, compacted to hard, white to pale grey, kaolinized, feldspathic sandstone below the lignite-bearing No. 2 zone. The formation, therefore, probably has a thickness in excess of 60 feet immediately west of the area in Alberta.

A fairly complete section of the Whitemud occurs on the east side of Medicine Lodge Coulée, in sec. 8, tp. 7, rge. 3, W. 4th mer., Alberta. This section, as given on a previous page, is 45·2 feet thick. The No. 1 zone is only 16 to 20 feet thick.

Nine feet of white weathering, light grey, fine- to medium-grained, massive, micaceous, feldspathic sandstone, identified as belonging to the No. 1 zone of the Whitemud formation, is exposed along the southwest side of Old Man On His Back Plateau in sec. 10, tp. 3, rge. 25. It is underlain by 2 feet of interbedded, very fine, light brown and light grey sandstone, then by 17 feet of very fine-grained, brown Eastend sand. Above the Whitemud are 24 feet of medium- to coarse-grained, hard, crossbedded, brown sandstone and basal clay pebble-conglomerate that belong to the Frenchman formation. The remainder of the Whitemud formation and the Battle formation have here been removed by the pre-Frenchman erosion.

The Whitemud beds exposed on the west side of Boundary Plateau, in the northwest quarter of sec. 15, tp. 1, rge. 23, are as follows:

	Thickness Feet
Battle Formation	
Shale, black, bentonitic; fissile, dark brown, organic shale and dark grey shale; green bentonite	15·3+
Whitemud Formation	
Shale, light grey weathering, medium grey to light brownish grey, bentonitic	5·2
Sand, argillaceous, pale brownish grey	0·5
Shale, arenaceous, white and yellow weathering, and partly kaolinized, feldspathic, fine sand; limonite	5·0
(Base not exposed)	

Origin. The origin of the Whitemud sediments has been thoroughly investigated and studied by McLearn (1935, pp. 104-110). The petrography of the sediments has been studied by Fraser (1935, pp. 93-103). The Whitemud beds are alluvial or subaerial deposits and are believed to have resulted from two stages of weathering; rapid mechanical weathering prior to transportation,

followed by chemical weathering in situ after deposition. It is believed that the sediments were derived originally by rapid mechanical weathering from the ancient landmass that existed on the site of Purcell and Selkirk mountains, west of the present Rocky Mountain trench. The derived sands, highly feldspathic, were transported eastward and deposited on the site of what now constitutes the Great Plains region. Conditions of deposition corresponded to those on an alluvial plain with shifting stream courses, shallow flood-plains, lakes and ponds, and low-lying but unsubmerged areas in a temperate climate.

Chemical weathering followed deposition on the alluvial plain prior to burial by later formations. McLearn postulates an almost entire cessation of deposition of sediments for very long periods to provide time for the high degree of alteration before burial. During this time he believes (Fraser *et al.*, 1935, p. 106) that periods of high or flood water and deposition may have alternated with periods of low water and weathering. These may have been seasonal. Chemical alteration resulted in the kaolinization of the feldspars, providing much interstitial clay in the sands, and, where this material was reworked, permitting the segregation of the clay into beds free of sand. Some refractory clay beds may have originated by chemical alteration of ordinary transported clay in place, and also by extreme alteration of some feldspathic sands beyond the stage of a kaolinized feldspathic sand or sandy clay.

Correlation. In the Cypress Lake map-area the Whitemud formation can be traced almost continuously eastward to the type locality at Whitemud. Westward, the lithological features and stratigraphic succession serve to correlate it with exposures at the western end of the Cypress Hills in Alberta. Neither vertebrate nor invertebrate fossils have been found in the Whitemud that are sufficiently diagnostic to serve for correlation purposes. A large, Upper Cretaceous flora was collected, but, as yet, such floras provide little information that can be used for correlation.

The correlation of the Whitemud has been discussed at length (Fraser *et al.*, 1935, pp. 34, 35) and the evidence summarized as follows:

"Until more satisfactory faunal or floral evidence is obtained, resort must be had to correlation by lithological resemblance and stratigraphic position. It has been proposed on these grounds that the Whitemud be correlated with some upper member of the Fox Hills in Montana. It may be compared on lithological grounds with the Colgate member, which is the upper member of the Fox Hills in eastern Montana, as redefined by Thom and Dobbin (1924). The presence of the same kind of white, sandy clays with evidence of alteration in place after deposition, the similar stratigraphic position, and the similar erosional unconformity above[1] suggest this correlation. Although the Colgate was originally defined as a member of the Lance, Thom and Dobbin (1924) and Dobbin and Reeside (1929) claim it is a part of, and the upper member of, the Fox Hills in eastern Montana. If this is so and the Whitemud is a correlate of the Colgate, the Whitemud is an equivalent of the upper Fox Hills and is pre-Lance in age."

R. W. Brown (1939) describes and discusses the fossil plants of the Colgate (Whitemud ?) member of the Fox Hills in the type area. Fossil plants are scarce in the type locality of the Fox Hills near Fox Ridge, between Cheyenne and Moreau Rivers, South Dakota. Brown made his largest collection from the Colgate at Iron Bluff, 8 miles southwest of Glendive, Montana. He finds that the Fox Hills flora appears to be intermediate between the floras of the Mesaverde and Laramie formations. According to Brown, the flora suggest a fairly moist or mesophytic environment, and a climate that must have been at least warm temperate.

[1] The term "Whitemud" as used in this quotation includes also beds referred to in the present report as those of the Battle formation, which overlies the Whitemud.

It is of considerable interest for comparison to reproduce here Brown's section at Iron Bluff as follows:

	Thickness Feet
"Hell Creek formation: sandstone, brown and platy at top; light grey, rusty, and cross-bedded below	41
"Fox Hills Sandstone: Colgate member; white, massive, partly stained sandstone	44
"Lower member; brown and yellow sandstone and grey and brown sandy shale	101
"Pierre shale; dark-coloured marine shale with fossiliferous concretions	75+"

The above section can be duplicated at many places in the Cypress Lake map-area where the upper beds of the Whitemud formation and the Battle formation have been removed by erosion and the crossbedded brown sandstone of the Frenchman formation rests directly upon the No. 1 zone of the Whitemud (*See* Plate III A). The 101 feet of brown sandstone comprising the Lower member of the Fox Hills in Brown's section above would equate with the 90 to 100 feet of brown sandstone comprising the Eastend in the Cypress Lake map-area. The Frenchman sandstone, as shown subsequently, is the correlative of the Hell Creek beds of eastern Montana. Though Brown does not indicate that the upper contact of the Colgate is an erosional unconformity, such is stated to be the case by A. G. Leonard (1908), by Knowlton (1909), and by Dobbin and Reeside (1930, pp. 14, 15), though no great importance was attached to the unconformity by these writers.

J. O. G. Sanderson (1931) has correlated a section of the beds of the Edmonton formation with the Whitemud and overlying beds of the western Cypress Hills. Russell (Russell and Landes, 1941, p. 91) makes the same correlation. Sanderson's section of the Edmonton in Red Deer River Valley consists of 25 to 40 feet of "very white sandstone or clayey sandstone" overlain by chocolate-brown coloured shale in which is one main tuff bed, named the Kneehills tuff. Russell, however, considers the white beds are more bentonitic than kaolinized. Sanderson correlated the white sandstone and clayey sandstone with the white kaolinized feldspathic sands and clays that comprise the Whitemud formation in the Cypress Hills. The dark brown shale and volcanic ash beds overlying the white beds he correlated with similar shale beds overlying the white sands and clays in the Cypress Hills, and here included with the Battle formation. As described subsequently, the dark brown to black, bentonitic shales of the Battle formation contain from one to three, light brownish grey, siliceous beds as much as a foot thick lying either at the top or bottom and, at places, in the centre of the formation. Sanderson presented analyses to show definite similarity in chemical composition of the light-coloured, volcanic "ash" bed at the top of the dark brown shale in the Cypress Hills to the Kneehills tuff. F. J. Fraser examined a sample from a 6-inch bed at the top of a 30-foot section of the dark brown shale in the Eagle Butte district at the west end of the Cypress Hills (Russell and Landes, 1940, p. 90) and found it "highly siliceous, and with few crystalline fragments, but does not show evidence of volcanic ash". The writer examined a sample from a similar bed at the base of the dark brown to black bentonite and bentonitic shale on the west side of Adams Creek, in the NE. ¼ sec. 7, tp. 7, rge. 28. This sample is highly siliceous. Many of the grains are of very fine sugary quartz; a large number are of opaline quartz; but the majority consist of highly irregular, very angular, extremely clear glassy quartz. Though generally blocky, some of the latter grains are long and tapered, almost shard-like. A little white mica is present. It would seem that the clear glassy quartz has not undergone transportation by water and it is not an aeolian sand. On the other hand, it may have had a volcanic origin.

Not only are the dark shales themselves very bentonitic in character, but bentonite forms a large part of the strata of the Battle formation. Though it may be unwise to assume that all bentonite is derived from volcanic ash, certainly that has been the origin for most if not all of the bentonite in the Bearpaw formation of this area. If the bentonite of the Battle formation reflects, as it probably does, long continued periods of volcanic activity, then the Battle formation and the underlying Whitemud formation may well be the direct correlatives of the dark chocolate-brown shale and underlying white sandstone and clayey sandstone described by Sanderson in Red Deer River Valley from the upper part of the Edmonton formation.

J. S. Stewart of the Geological Survey (personal communication) measured a section from the Edmonton formation a mile northwest of Gleichen, in the SW. ¼ sec. 24, tp. 22, rge. 23, W. 4th mer. This is as follows:

	Thickness Feet
Glacial till to prairie level	4·0
Dark grey clay shale, weathers loose	14·0
Hard, dark grey, shaly band, definitely identified as volcanic ash	1·0
Dark grey clay shale, harder than upper shale and may contain some ash	19·0
Shale, brown	1·4
Sandy shale, weathers light grey to white	4·0
Pea-green, sandy shale	3·0
Pale buff to light grey sandstone, weathers nearly white	5·0
Base unexposed.	

The 35·4 feet of beds immediately below the glacial till may be correlated with the Battle formation of the Cypress Lake map-area, and the lower 12 feet would appear to correlate with the Whitemud formation.

The correlation of the uppermost Cretaceous sediments exposed in the Cypress Hills area with those exposed west of the Sweetgrass arch in Alberta is a problem that cannot be solved with the evidence presently available, but is one that will require much additional study. The following discussion is included for the purpose of outlining the problem and to present a possible line of investigation.

The correlation of the Bearpaw beds across the Sweetgrass arch and the correlation of the Oxarart sandstone member with the Blood Reserve sandstone has been discussed. On the basis of this correlation it has been shown that the Eastend formation is probably correlative with some considerable part of the St. Mary River formation. It is with the correlation of the Upper Cretaceous sediments lying above the Eastend formation in the Cypress Hills area with the sediments lying stratigraphically above and possibly including the upper part of the St. Mary River formation west of the Sweetgrass arch that this discussion is particularly concerned.

Throughout Upper Cretaceous time the same changes in the conditions of sedimentation occurred west of the Sweetgrass arch as in the Cypress Hills area, and are recorded in each instance by the respective stratigraphic sections up to and including the Blood Reserve sandstone and its counterpart east of the arch the Oxarart sandstone member of the Bearpaw formation. West of the arch the St. Mary River formation immediately succeeds the Blood Reserve sandstone. This formation, as indicated by its fossils and as previously discussed, is marine in its lower part and becomes brackish to freshwater in character near its top. East of the Sweetgrass arch marine conditions prevailed longer, as demonstrated by the 200 feet of Bearpaw shales and sandstones deposited above the Oxarart member. The overlying Eastend formation represents, like the St. Mary River formation, a transition from marine to freshwater conditions of sedimentation. Immediately overlying the Eastend and St. Mary River for-

mations are two groups of beds, those of the Whitemud in the east and those of the Willow Creek in the west, deposited under rather special conditions, chief of which was a rising and falling water table or, in other words, alternating cycles of wet and dry periods.

The thickness of the Willow Creek beds is not readily determinable in the Plains because of incomplete sections, but it has been estimated at anywhere from 500 to 1,000 feet. The strata consist of non-marine beds of alternating purplish, yellow, red, green, and grey clays, with sands and sandy shales containing numerous, small, white, calcareous nodules and thin, black, carbonaceous shale beds. In discussing the origin of these variegated beds, Williams and Dyer (1930, pp. 60, 61) quote Barrell, who has shown that "red beds may be formed by the exposure of sediments on flood-plains under conditions of semi-arid climate. The iron-bearing minerals break down in whole or in part during wet seasons and become oxidized to the ferric condition during dry seasons, when, due to the lowering of the water table, the sediments become exposed to the atmosphere. Alternating beds of oxidized and partly oxidized sediments would be formed as a result of cycles of dry and wet years. On consolidation into rock such beds would show variations of colour from red, through yellow or brown, to grey or green".

Though other theories are postulated, Barrell's explanation appears the most logical for the development of a widespread and relatively thick series of Willow Creek beds. This is also the same climatic condition postulated by McLearn (Fraser *et al.*, 1935, p. 106) as necessary, during the stage of chemical alteration, for the origin of the Whitemud sediments. Nowhere else in Upper Cretaceous time is there evidence of alternating dry and wet periods in the western plains, yet the widespread distribution of Whitemud sediments attests to the existence of such climatic conditions over a large part of southern Saskatchewan. Widespread climatic conditions such as these are believed by McLearn to have existed for a long period in Saskatchewan, and must have been reflected in the sediments of Alberta unless their products were eroded. There are, however, no other sediments of comparable origin in the Upper Cretaceous of Alberta, and no unconformities below the Willow Creek beds.

Though there is considerable difference in the thicknesses of the two groups of sediments, it should be noted, in discussing the origin of Whitemud sediments, that McLearn postulates, after deposition of the feldspathic sands, an almost entire cessation of sedimentation for a long period to provide time for the high degree of chemical alteration prior to burial. During this period of non-deposition in the Cypress Lake area, sedimentation under the existing climatic conditions may have continued in the western Alberta plains. For the same reason the difference in lithology of the sediments comprising the two formations may be a function of the quantity of sediment supplied to the two areas within the same period and under the same general climatic conditions.

Palæontologic evidence for the age and correlation of the Willow Creek beds is very meagre, inconclusive, and, according to Russell and Landes (1940, p. 93), such fossils as have been collected came from the upper part of the formation. The correlation of the beds comprising this part of the stratigraphic section on either side of the Sweetgrass arch remains, therefore, a matter for further study.

BATTLE FORMATION

The name "Battle formation" is here proposed for a group previously described as zone 4 of the Whitemud formation (McLearn, 1928, p. 27; Fraser *et al.*, 1935, p. 28). It consists of dark brown to black and olive-green to greenish grey shales, bentonitic shales, and bentonite; greenish brown to greenish grey

silts; and fine, argillaceous sands. These beds overlie the Whitemud and underlie the Frenchman formation. Whereas even the sandstones of the Whitemud formation show some chemical alteration to kaolinite, the beds included in the Battle formation show no evidence of such chemical alteration. They, therefore, reflect a sharp change in conditions of sedimentation from those under which the Whitemud beds were deposited. Furthermore, the only bentonite observed in the Whitemud formation occurs at the west end of the Cypress Hills, whereas the Battle beds include a relatively high proportion of bentonite and bentonitic shales as well as a number of siliceous beds of possible volcanic origin. If, as seems probable, bentonite has been derived by alteration of volcanic material it reflects a period of pronounced volcanic activity. In addition, the beds comprising the formation are lithologically distinctive and provide a useful mapping unit over a wide area. For these reasons this group of beds is here provided with a formational name.

The formation may be divided conveniently into two members. The lower member consists of bentonitic weathering, dark chocolate-brown to black, bentonitic shale. It ranges in thickness from 5 feet to 30 feet, and is commonly 20 feet thick. Beds as much as a foot thick of light brown, siliceous material and of possible volcanic origin occur in many places at the top and bottom of the lower member, and, in a few places, a layer of such material is also present in the central part of the member. The beds are everywhere conformable with those of the underlying Whitemud formation and the contact is sharp.

The upper part of the formation is distinctly greenish. It includes interbedded olive-green to greenish grey shales, silts, argillaceous sands, and olive-green bentonite. This part of the formation varies in thickness up to an observed maximum of 10 feet. The upper surface is generally in unconformable contact with coarse basal sandstone of the Frenchman formation. Where pre-Frenchman erosion of the Battle has been negligible, there is, in a few places, difficulty in fixing the contact.

Distribution. The Battle formation is widespread and is well exposed in the valley of Frenchman River, along Adams Creek, and along Battle Creek in ranges 29 and 30. Scattered exposures occur at a few points along the north slopes of the Cypress Hills and on Boundary Plateau. The formation had been completely removed by erosion in the vicinity of Old Man On His Back Plateau prior to the deposition of the beds of the succeeding Frenchman formation.

Detailed Description. A good section across the formation and extending up to the base of the Ravenscrag formation is exposed on the east side of Adams Creek, in the NE. ¼ sec. 8, tp. 7, rge. 28, as follows:

	Thickness Feet
Ravenscrag Formation	
Silts and shales, grey and buff; lignite	11·8+
Frenchman Formation	
Sandstone, chiefly coarse-grained, greenish brown; shale, grey to olive-green; limonitic zone at base	50·3
Battle Formation	
Shale, olive-green and dark greenish grey	8·4
Shale, dark brown to black, bentonitic	11·5
Shale, pale brownish grey, siliceous	0·8
Shale, dark brown to black, bentonitic	5·0+
Thickness	25·7+

About $\frac{1}{4}$ mile southeast of the above, along the north side of a small creek, is the following section:

Ravenscrag formation (and base of lignite seam)

Frenchman Formation	Thickness Feet
Sandstone, chiefly greenish brown, coarse-grained, compacted; shale, olive-green to brownish; limonitic zone at base	47·3
Battle Formation	
Silt and bentonitic shale, olive-green to dark greenish brown	10·0
Shale, dark brown, bentonitic, siliceous	1·0
Shale, dark brown to black, bentonitic	12·3
Shale, pale brownish grey, siliceous	0·8
Shale, dark grey to black	1·0+
Thickness	26·1+

Farther north, on the east side of Adams Creek, in the NE. $\frac{1}{4}$ sec. 6, tp. 8, rge. 28, a section across the Frenchman and overlying Battle formations illustrates the lithology where erosion prior to deposition of the Frenchman sediment was small.

Ravenscrag Formation	Thickness Feet
Grey shale and fine sand; yellow silt; a 6-foot lignite bed at base	50·0+
Frenchman Formation	
Greenish grey shale with thin beds of greenish grey, fine sand; bentonite	26·3
Battle Formation	
Shale, greenish grey; with thin beds of greenish grey silt and fine-grained sand	7·0
Shale, dark brown to black, bentonitic	4·0
Shale, light brownish grey, siliceous; with laminæ of brown to black, organic material	0·3
Shale, dark brown to black, bentonitic	2·4
Shale, light brown, siliceous	0·9
Shale, dark greyish brown, bentonitic	2·0+
Thickness	16·6+

The following section occurs on the northeast slope of a high ridge on the west side of Battle Creek, in the NW. $\frac{1}{4}$ sec. 2, tp. 8, rge. 30:

Frenchman Formation	Thickness Feet
Sandstone, compacted to hard, medium- to coarse-grained, brown and grey, thickly bedded and crossbedded; with limonitic silt laminæ	58·0+
Battle Formation	
Shale, olive-green, bentonitic	3·0
Shale, light brown, siliceous	0·5
Shale, dark brown to black, bentonitic	16·0+
Thickness	19·5+

On the west side of Battle Creek Valley, about the middle of sec. 17, tp. 7, rge. 29, is the following section:

Frenchman Formation	Thickness Feet
Sandstone, greenish brown, fine- to medium-grained; with limonitic laminæ and limonite layer at base	41·2+

Battle Formation	Thickness Feet
Shale, dark green, bentonitic	1·0
Shale, olive-green, bentonitic	0·7
Shale, light brown, siliceous	1·0
Shale, dark grey and black, bentonitic	21·0
Shale, light brownish grey, siliceous	0·5
Thickness, Battle formation	24·2
Whitemud Formation	
White weathering silts, shales, and clays	25·5+

Numerous exposures of the Battle formation occur along the valley of Frenchman River east of Ravenscrag. Some of the more representative sections follow, the most easterly one measured being in the NW. ¼ sec. 26, tp. 6, rge. 23, W. 3rd mer:

Ravenscrag Formation	Thickness Feet
No. 1 lignite seam.	
Frenchman Formation	
Sandstone, dark greenish grey, medium-grained	13·0
Battle Formation	
Shale, dark green	3·0
Shale, dark grey to black, bentonitic	13·0
Thickness	16·0

At ¼ mile west of the above section is the following:

Ravenscrag Formation	
No. 1 lignite seam.	
Frenchman Formation	
Sandstone, greenish brown, fine- to medium-grained; shale, greenish grey	12·3
Battle Formation	
Shale, dark grey to black, bentonitic to base of formation	18·3

At ¼ mile west of the above section is the following:

Ravenscrag Formation	
No. 1 lignite seam.	
Frenchman Formation	
Interbedded dark green sand, sandy shale, and silty shale	12·0
Battle Formation	
Shale, dark grey to black, bentonitic (to base of formation)	7·2

In the NE. ¼ sec. 22, tp. 6, rge. 24, is the following section:

Frenchman Formation	
Sandstone, rich brown, clean, coarse-grained; irregular hard layers and concretions	42·7
Battle Formation	
Bentonite, green, and shale, bentonitic	2·3
Shale, dark grey to black	5·2
Sandstone, fine- to medium-grained	3·6
Shale, dark grey to black (to base of formation)	10·6
Thickness, Battle formation	21·7

East of this section, towards Ravenscrag Butte, the beds of the Battle formation have been almost entirely removed by erosion and replaced by beds of the coarse, lower sandstone of the Frenchman formation.

Along the south side of Frenchman River Valley east of Ravenscrag similar sections of the Battle formation were encountered. From the east edge of the map-area to the west side of sec. 17, tp. 6, rge. 23, a nearly normal section is present, but west of this point to west of Table Butte the beds have been eroded prior to the deposition of those of the Frenchman formation. West of Table Butte only beds of older formations outcrop.

In the southern part of the map-area, beds of the Whitemud and Frenchman formations are exposed along the southern edge of Old Man On His Back Plateau. However, the beds of the Battle formation as well as much of the Whitemud have been removed by erosion prior to the deposition of the Frenchman formation. At Boundary Plateau, in the middle of sec. 15, tp. 1, rge. 23, is the following section:

Ravenscrag Formation	Thickness Feet
Lignite seam	11·0+
Frenchman and Battle Formations	
Shale, olive-green, bentonitic; silt with some greenish brown, medium-grained sandstone; poorly exposed	59·8
Battle Formation	
Interbedded light and dark grey shale, greenish grey, bentonitic shale, and silt	8·0
Shale, brown, fissile, organic	0·5
Shale, dark grey, fissile	1·5
Shale, brown, fissile, organic	0·2
Bentonite, green	0·2
Shale, light and dark grey	0·6
Interbedded, dark brownish grey shale and brown, fissile, organic shale	1·9
Shale, dark brownish grey and dark grey, organic	1·7
Shale, brown, fissile, organic	0·7
Shale, black, bentonitic (to base of formation)	8·9
Thickness, Battle formation	24·2

This section is quite different from those to the north, but there is no question of the 8·9 feet of black, bentonitic shale at the base of the Battle formation correlating with the lower division of this formation to the north. The overlying 7·3 feet is composed chiefly of organic shale with a little bentonite. These beds do not occur in the section of the Battle formation to the north, but probably represent a more organic phase of the upper part of the lower division of the formation as exposed there. How much of the overlying 59·8 feet is Battle formation and how much is Frenchman could not be determined. As the thick lignite seam at the base of the Ravenscrag is 84 feet above the top of the Whitemud, it would appear to correlate more closely with the No. 2 or No. 3 lignite seams of the Ravenscrag in Frenchman River Valley than with the No. 1 lignite seam.

The Battle formation was not studied generally in the Head of the Mountain area at the west end of the Cypress Hills in Alberta, but was encountered in one section measured on the east side of Medicine Lodge Coulée. In the SE. ¼ sec. 8, tp. 8, rge. 3, W. 4th mer., is 5 feet of the dark brown to black, bentonitic shale, typical of the lower division of this formation. It is underlain by beds of the Whitemud formation, and is overlain unconformably by the medium to

coarse, greenish brown Frenchman sandstone. In other sections along the east side of Medicine Lodge Coulée and south of the above section it was found that erosion had removed the beds of the Battle formation, and that the greenish brown sandstone of the Frenchman lay directly upon lower Whitemud beds.

Age and Correlation. The possible correlation of the Battle formation with similar beds of the Edmonton formation in central Alberta has already been discussed. No fossils other than tap roots are present, and correlation must be based entirely upon lithology and stratigraphic position. As the Battle beds underlie those of the Frenchman formation unconformably, they are definitely of late Upper Cretaceous age.

FRENCHMAN FORMATION

The name "Frenchman" is here assigned to beds previously described as Lower Ravenscrag. They lie above the Battle formation and below beds formerly referred to the Upper Ravenscrag, but herein designated simply as Ravenscrag. The formation consists chiefly of medium- to coarse-grained, massive sandstones (*See* Plate IVA).

The former Ravenscrag formation, originally defined by Davis (1918, p. 9), was divided on lithological and faunal grounds into an Upper and Lower Ravenscrag (McLearn, 1929, p. 38; F. J. Fraser *et al.*, 1935, pp. 39, 40), now named respectively the Ravenscrag and Frenchman formations. Formational names are warranted for the following reasons. The Frenchman formation consists essentially of thick, massive or coarsely crossbedded, medium-grained sandstones with rare coaly beds. In marked contrast the Ravenscrag formation consists of thinly bedded, fine-grained sands, silts, and shales with numerous coal beds and lignitic laminæ. Each group, therefore, reflects distinctly different conditions of sedimentation. The Frenchman beds constitute a distinctive, widespread, mappable unit. *Triceratops* fauna has been identified from the Frenchman beds over a wide area, whereas no reptile remains have yet been found in the overlying beds. The presence of *Triceratops* definitely places the Frenchman formation in the Cretaceous, whereas faunal and floral evidence in general indicates that the Ravenscrag beds are of Paleocene age (F. J. Fraser *et al.*, 1935, p. 52). Fossils are not sufficiently numerous to define the exact palæontological boundary, and it is possible that some of the beds included in the lower part of the Ravenscrag are of Cretaceous age. However, it is considered inadvisable to use the same name for two lithologically distinctive units in which the greater part of the beds in each are definitely assigned by palæontological evidence to two different eras. Because the Lower Ravenscrag beds are well exposed along Frenchman River, and the type area may be considered to be along this river between Ravenscrag and Eastend, the name Frenchman formation is here proposed for these beds.

Beds on Morgan (Rocky) Creek, in tp. 1, rge. 5, W. 3rd mer., now known to correspond approximately to Frenchman, were called Division B of the Lignite Tertiary by Dawson (1875), Laramie by McConnell (1885), and Lance by Rose (1916). They did not, however, recognize them elsewhere in the southern Plains. Davis (1918) included them along with other beds in the formation he named Ravenscrag.

It remained, however, for McLearn (1928, 1930) to recognize an erosional unconformity at the base of the Lower Ravenscrag (Frenchman formation). He redefined the Ravenscrag formation, divided it into Lower and Upper Ravenscrag, and described the unconformity at its base along Frenchman River in the Eastend area. The erosional interval is not long, and the depth of erosion has not been found to exceed 200 feet. However, it has been recognized over a

wide area extending as far east as Big Muddy Valley (McLearn, 1928, p. 30; 1929, p. 29; 1930, p. 54; F. J. Fraser *et al.*, 1935, p. 37). To the west it has been observed by the writer along Adams and Battle Creeks at the west side of the Cypress Lake map-area; along the south side of Old Man On His Back Plateau, in the southwest corner of the same area; and in sections studied along the east side of Medicine Lodge Coulée at the west end of the Cypress Hills in Alberta. As pointed out by McLearn, the unconformity has assumed unusual significance because it has affected economic resources by the removal of valuable Whitemud clays over a large part of the region. Dobbin and Reeside (1929) have not regarded the unconformity between the corresponding Lance or Hell Creek (Frenchman) and underlying Colgate (Whitemud) strata in the Great Plains area of the United States as of great stratigraphic significance.

Distribution. The Frenchman formation is best exposed along Frenchman River between Eastend and Ravenscrag; along Adams Creek on the west side of the map-area; and along the southwest slopes of Old Man On His Back Plateau. Other outcrops occur along Battle Creek, in tps. 6 and 7, rges. 29 and 30; along the west side of Table Butte, in the SE. $\frac{1}{4}$ tp. 6, rge. 24; and along creeks north of, and tributary to, Frenchman River west of Ravenscrag.

Lithology, Thickness, and Contacts. The formation is composed essentially of sandstone that is massive, fine- to coarse-grained, coarsely crossbedded, compacted to hard, greenish brown to brown, clean, and generally well sorted. Concretionary masses occur at places; siltstone pebble beds are common; and limonitic siltstone and thin shale laminæ were noted in some exposures. The sandstone is generally feldspathic, and at places biotite flakes were observed. Brown, organic shale may be present, and black, carbonaceous shale and lignitic partings were noted at places along bedding planes in the sandstone.

Intercalated with the thick sandstone lenses, and commonly occurring at the top of the formation, are beds of greenish grey to green, bentonitic shale, silt, and fine, shaly sand. At many places in the upper few feet of the formation is an olive-green bentonite bed several feet thick. These beds characterize the closing stages of Cretaceous sedimentation.

The lower contact is marked by the erosional unconformity already referred to (*See* Figure 2), and its stratigraphic position, relative to underlying beds, is quite irregular (*See* Plate III B). However, where erosion has been slight, beds of the Battle formation pass upwards into beds of the Frenchman formation with only slight changes in lithology. No dark beds are present. Greenish brown, clean, fine- to medium-grained sandstone makes its appearance, interbedded with green shales and silts, and the contact is placed arbitrarily at the base of the lowest thick sandstone bed. This type of contact is exceptional, and the lower contact where exposed is, in general, indicated by a marked erosional unconformity.

The Frenchman formation ranges in thickness from 10 to 200 feet within the map-area. The upper Frenchman contact is drawn at the base of a prominent coal seam or seams that constitute a carbonaceous zone. This zone rises, stratigraphically, from east to west across the map-area. Figure 2 illustrates the stratigraphic relations of the various coal seams to one another and to the Whitemud formation.

The coal seam east of Ravenscrag is known as the No. 1 seam. It lies 25 feet above the contact of the Whitemud and Battle formations[1]. Here, along

[1] The interval from the coal seam immediately above the Frenchman to the contact between the Whitemud and Battle formations crosses an unconformity. No angular disconformity is present, and the unconformity is more of the nature of scour and filling along local channels. No good datum or reference plane is available in the overlying Ravenscrag. The contact between the Whitemud and Battle, therefore, provides the most convenient reference plane. It can be assumed that where erosion has failed to penetrate below this contact it has indeed been of a very minor nature.

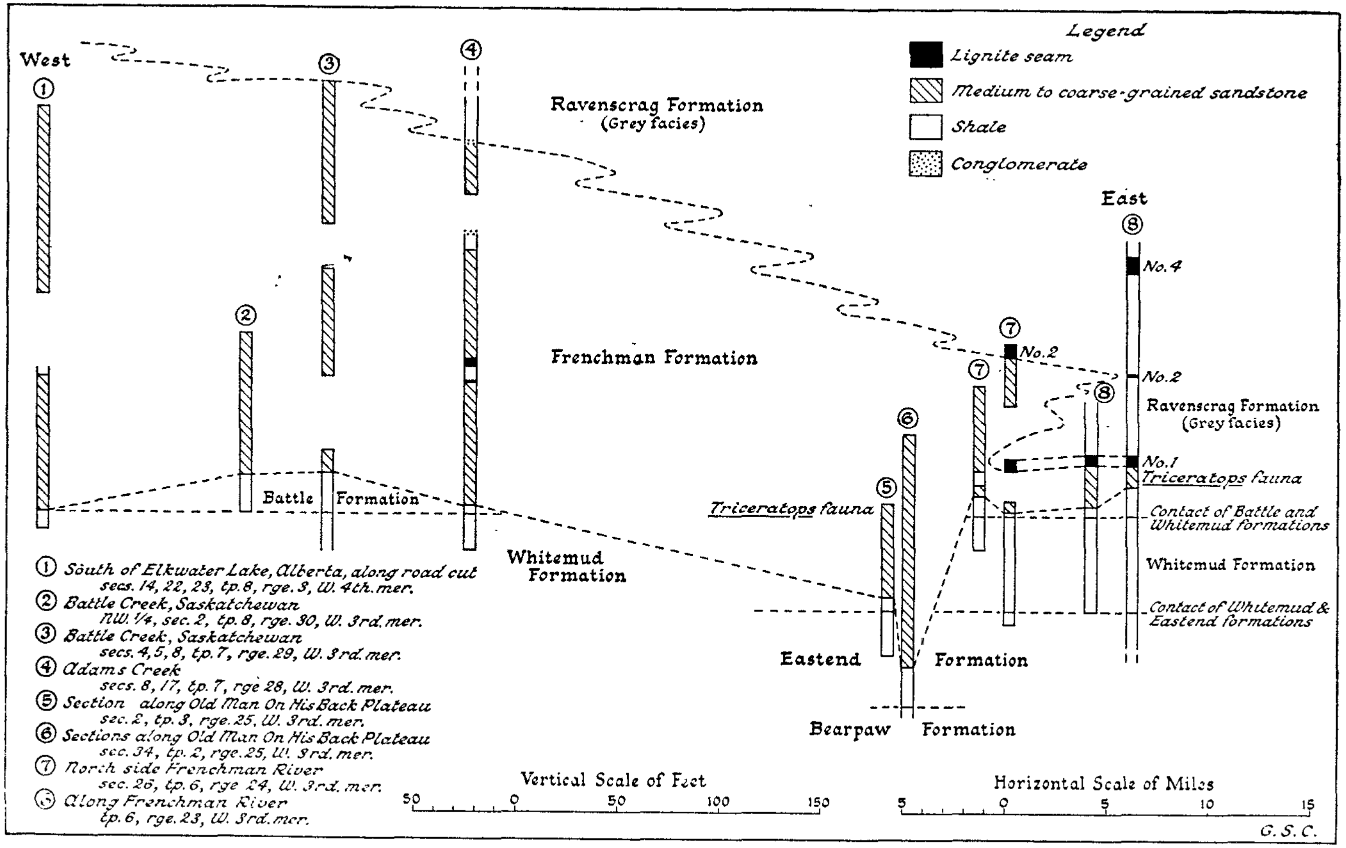


Figure 2. Diagram illustrating relations of the Frenchman formation to underlying formations and to the overlying Ravenscrag formation. Where present the contact between the Battle and Whitemud formations has been used as a datum, but where the Whitemud has been removed by erosion prior to deposition of the Frenchman beds lower horizons have been used, as indicated.

Frenchman River at the east edge of the map-area, the Frenchman formation appears to be thinnest, despite the fact that at Knollys, 4 miles to the east, it is 20 to 80 feet thick (F. J. Fraser *et al.*, 1935, p. 42). On Ravenscrag Butte and opposite it, on the south side of Frenchman River, the formation has a thickness of only 10 to 15 feet and is represented by interbedded sands and shales. The contact there with the underlying Battle formation is difficult to place. Farther east and west sandstone becomes abundant and the formation becomes more typical of the Frenchman beds.

A mile and a half northwest and north of Ravenscrag, in the NE. $\frac{1}{4}$ sec. 26, tp. 6, rge. 24, W. 3rd mer., the Frenchman formation is 77 feet thick. There the coal seam at the top of the formation appears to be the correlative of a seam known as the No. 2 coal seam on Ravenscrag Butte. It lies 82 feet above the Whitemud-Battle contact. The No. 1 seam is also present, and can be traced for 2 miles to the east. Its base is 28 feet above the Whitemud formation. Near this section the typical medium- to coarse-grained Frenchman sandstone below the No. 1 coal seam has cut down into and rests unconformably upon the lowest or No. 1 zone of the Whitemud formation. Above this coal seam, 3·1 feet thick, is as much as 25 feet of interbedded buff sands, silts, shales, and lignitic laminæ succeeded by 2·2 feet of chiefly coarse, clean, reddish to greenish brown, typical Frenchman sandstone overlain by 4 feet of grey shale to the base of No. 2 coal seam. It appears, therefore, that the buff silts and grey shales lying between the No. 1 and No. 2 coal seams on Ravenscrag Butte, and which belong lithologically to the Ravenscrag formation, pass laterally westwards into the coarse sandstone of the Frenchman formation, and that the upper contact of this formation rises stratigraphically to the west (*See* Figure 2).

A similar condition was observed along the east side of Adams Creek in the western part of the map-area. Here the typical Frenchman sandstone and associated beds have a thickness of 50 to 65 feet. The upper contact is drawn at the base of a coal seam that is 70 to 75 feet above the top of the Whitemud formation. It occupies approximately the same stratigraphic position relative to the top of the Whitemud as does the No. 2 coal seam on Ravenscrag Butte. However, in the SW. $\frac{1}{4}$ sec 17, tp. 7, rge. 28, there are 54 feet of massive, buff to brown, medium-grained, coarsely crossbedded sandstones above the coal seam at the top of the typical Frenchman beds. These beds pass laterally to the north and south into the typical beds of grey shale and buff silts of the grey facies of the Ravenscrag formation, and probably represent an eastward tongue of beds comprising the upper part of the Frenchman formation to the west. The combined beds have a total thickness of 100 to 120 feet. No fossils were found in the beds and a definite age cannot be assigned to them. They could, of course, represent a local coarsening of the normal sediments of the overlying Ranvescrag formation from east to west and although no additional evidence was obtained in the western part of the map-area to confirm such a change in Ravenscrag sedimentation, the beds are for the present mapped tentatively with that formation.

Composite sections in secs. 4, 8, and 9, tp. 7, rge. 29, W. 3rd mer., on the west side of Battle Creek, indicate that the coarse-grained, massive, and crossbedded, hard sandstone overlying the Battle formation unconformably extends from at least 150 to as much as 180 feet above the top of the Whitemud formation. Here again fossils were not found, but the persistent lithology and its resemblance to that of typical Frenchman beds to the east indicate a possible correlation, and suggest that the upper contact of the formation has risen stratigraphically some 125 feet above its position east of Ravenscrag. It is possible that some of these beds may represent the coarser equivalents of the fine-grained sediments of the Ravenscrag formation that occupy the same relative stratigraphic position to the east.

On the east side of Battle Creek, in the NE. ¼ sec. 2, tp. 8, rge. 30, 58 feet of coarse-grained, indurated, buff and grey, crossbedded sandstones overlie the Battle formation unconformably. These beds extend to at least 75 feet above the top of the Whitemud formation. The upper part of the formation, here, has been eroded.

The upper part of the Frenchman formation has likewise been eroded on Old Man On His Back Plateau. The remaining beds have a total thickness of 117 feet. Here the base is in unconformable contact with lower beds of the Eastend formation, a total of 130 to 150 feet of beds, comprising those of the Whitemud and Battle formations, together with 30 to 40 feet of Eastend beds having been removed by erosion prior to the deposition of the Frenchman beds. Allowing a thickness of 60 feet for the Eastend formation, and 55 feet for the Whitemud, it is estimated that the No. 1 coal seam of the Ravenscrag area would occur 15 to 20 feet above the top of this section. However, it is more probable that the upper contact of the Frenchman formation would here be at an horizon stratigraphically above the No. 1 coal seam, as it is at Boundary Plateau. There the top of the formation, as marked by the prominent coal seam, is 84 feet above the top of the Whitemud or 75 feet above the top of the section at Old Man On His Back Plateau. The thickness of the formation in this area is, therefore, estimated to be between 135 and 200 feet, and is probably nearer the latter figure. The formation is at a minimum in Frenchman River Valley east of Ravenscrag, where it is only 10 to 15 feet thick (*See* Figure 2).

Detailed Description. A number of sections crossing the Frenchman and Battle formations below the No. 1 coal seam in the area east of Ravenscrag follow. These are representative of sections encountered on both the north and south sides of Frenchman River where the thickness of the formation is at a minimum. The beds consist mainly of sandstone, at the eastern edge of the map-area, and pass laterally westwards into shale with minor amounts of sandstone, and, still farther west, into chiefly sandstone. The section in the NE. ¼ sec. 27, tp. 6, rge. 23, is as follows:

	Thickness Feet
Ravenscrag Formation	
No. 1 lignite seam.	
Frenchman Formation	
Shale, grey to purplish grey	2·0
Shale, greenish grey	6·0
Sandstone, greenish brown, fine- to medium-grained	4·3
Thickness	12·3
Battle Formation	
Shale, dark grey to black, bentonitic	18·3

At ¼ mile west of the above section is the following:

Ravenscrag Formation	
Frenchman Formation	
Shale, dark brownish grey	0·5
Shale, green, silty, and bentonitic	6·3
Sand, dark green, interbedded with sandy shale and silt	5·0
Sand, dark brown to greenish brown	0·2
Thickness	12·0
Battle Formation	
Shale, dark grey to black, bentonitic	7·2

On the south side of Frenchman River, in the SW. ¼ sec. 21, tp. 6, rge. 23, 2 miles east of Ravenscrag, is a section in which the upper contact of the formation is higher stratigraphically than at the eastern edge of the map-area. It is as follows:

	Thickness Feet
Ravenscrag Formation	
Lignitic beds (No. 2 seam ?).	
Frenchman Formation	
Shale, green to grey, bentonitic	5·0
Sandstone, brownish grey, crossbedded, medium-grained	30·0
Sandstone, coarse-grained, buff to brown, coarsely crossbedded, concretionary	13·0
Total thickness	48·0
Battle Formation	
Shale and argillaceous sand, olive-green to grey-green	10·0
Shale, dark grey to black (to top of Whitemud formation)	9·4
	19·4

The vertical interval from the top of the Whitemud formation to the base of the lignitic beds at the base of the Ravenscrag formation is here 67·4 feet.

The section previously referred to 1½ miles northwest and north of Ravenscrag in the NE. ¼ sec. 26, tp. 6, rge. 24, W. 3rd mer., is as follows:

	Thickness Feet
Ravenscrag Formation	
Lignite beds (No. 2 seam ? and shale)	4·5
Frenchman Formation	
Shale, grey to dark grey	4·0
Sandstone, greyish brown, medium- to fine-textured	5·3
Shale, dark grey, interbedded with buff silt and brown, organic laminæ	1·0
Sandstone, coarse-grained, brown, crossbedded	15·8
Interbedded greenish grey, soft shale and buff, fine sandstone; light grey shale 0·5 foot thick at top	8·0
Lignite bed	0·5+
Concealed	16·3
Lignite and black, fissile, carbonaceous shale (No. 1 lignite seam?)	3·1
Concealed	17·0
Sandstone, rusty brown, coarse-grained, crossbedded (to top of Whitemud formation)	13·0+
Total thickness, Frenchman beds	84·0

Fifty feet west of the above section the lower, coarse sandstone has cut down only into the Battle formation, and the vertical interval from the base of the lignite beds to the Whitemud-Battle contact could be measured, and is 82 feet.

A mile farther southwest, in the NE. ¼ sec. 22, tp. 6, rge. 24, 42·7 feet of brown, clean, medium- to coarse-grained sandstone, with irregular hard layers and concretions, lie above the Battle formation and below the Ravenscrag. Here continuous exposures of the coarse Frenchman sandstone extend above the eroded surface of the Battle formation. The beds at the top of the section are at a stratigraphic horizon 64 feet above the Whitemud-Battle contact. At places in this vicinity the hard sandstones and conglomerates of the Cypress Hills formation overlie unconformably the sandstones of the Frenchman formation.

West of the above section, with the exception of a small outcrop of coarse sandstone overlain by Cypress Hills conglomerate in the NE. ¼ sec. 22, tp. 6, rge. 24, no further exposures of the Frenchman formation occur along the lower southern slopes of the Cypress Hills until Adams Creek is reached on the west side of the map-area. Beds of the Cypress Hills formation directly overlie lower Eastend and Bearpaw beds throughout this distance. In the NW. ¼ sec. 11, tp. 7, rge. 23, 2½ miles due north of Ravenscrag Butte, is the following section:

	Thickness Feet
Ravenscrag Formation: (lignite)	
Frenchman Formation	
Shale, greenish brown to olive-green, dark at top	13·7
Sandstone, coarse-grained, rich brown, clear, fine-grained at top; sandstone concretions; abundant reptile bone fragments	34·0
	47·7
Battle Formation	
Shale, olive-green	2·0+

The Frenchman formation along Adams Creek can be illustrated by the following sections, commencing with that in the NE. ¼ sec. 8, tp. 7, rge. 28, on the east side of the creek:

	Thickness Feet
Ravenscrag Formation	
Silts, shales, grey to buff; lignite	11·8+
Frenchman Formation	
Shale, dark brownish grey	1·0
Shale, olive-green, bentonitic	2·0
Shale, greenish brown to olive-green; with minor amounts of silt near base	6·2
Sand, coarse, greenish brown	1·1
Shale, grey; limonitic layers	0·2
Sandstone, coarse-grained, greenish brown	39·6
Rusty, limonitic zone	0·2
Thickness of Frenchman beds	50·3
Battle Formation	
Shale, olive-green to black, bentonitic	25·7+

About ¼ mile southwest of the above, along the north side of a small creek, is the following section:

	Thickness Feet
Ravenscrag Formation (and base of lignite seam)	
Frenchman Formation	
Shale, dark grey	0·5
Shale, olive-green, bentonitic	3·7
Silt, greenish brown	3·0
Sandstone, greenish brown, coarse-grained, compacted	40·0
Limonite and silt	0·1
Thickness	47·3
Battle Formation	
Shale, chiefly, olive-green to black, bentonitic	26·1+

A section on the west side of Adams Creek, in the SE. ¼ sec. 18, tp. 7, rge. 28, is as follows:

	Thickness Feet
Lignite (Ravenscrag formation)	1·9
Frenchman Formation	
Shale, grey	1·0
Interbedded argillaceous sandstones and limonitic silt beds; biotite flakes	2·0
Sandstone, massive, greenish and brownish grey, coarse-grained, feldspathic	27·5
Shale, black; limonite	1·5
Sandstone, brownish grey, compacted	6·0
Sandstone, coarse, massive and crossbedded, brown and greenish brown to brownish grey, compacted to hard, feldspathic, clear	21·0
Concealed	16·0
Battle Formation (lower beds only)	
Shale, grey to dark brown to black, bentonitic	7·0+
Whitemud Formation	
Sandstone, white to light grey to pale yellow, kaolinized, feldspathic; some white weathering clays	8·0+

The section previously referred to on the east side of Adams Creek, in the SE. ¼ sec. 17, tp. 7, rge. 28, is as follows:

	Thickness Feet
Unconsolidated sand and gravel.	
Ravenscrag Formation	
Finely interbedded sandstone, shale, and silt; lignitic laminæ	142·0
Frenchman Formation (?)	
Sandstone, fine- to medium-grained, coarsely crossbedded, buff to brown	54·0
Lignite and black, carbonaceous shale	3·0+
	57·0
Frenchman Formation	
Shale, brownish grey	1·0
Shale, greenish grey; silt	6·2
Shale, organic, black, fissile	0·2
Sandstone, coarse, greenish brown to brown	60·0
	67·4
Battle Formation	
Shale, bentonitic, dark brown to black	5·9

The vertical interval from the top of the Whitemud formation to the top of the normal Frenchman formation is here 73 feet, and to the top of massive sandstone beds that may belong to this formation, 120 feet.

A section across these beds, in the NE. ¼ sec. 6, tp. 8, rge. 28, on the east side of Adams Creek (opposite Boyd's ranch house) closely resembles the sections along Frenchman River east of Ravenscrag. It is as follows:

	Thickness Feet
Ravenscrag Formation (Grey Facies)	59·4
Lignite seam (comminuted in part)	6·0

Frenchman Formation	Thickness Feet
Shale, dark brownish grey	0·5
Bentonite and bentonitic shale, olive-green	3·0
Interbedded greenish grey shale and greenish grey sand; former predominates	18·5
Sandstone, greenish grey, clean, fine- to medium-grained	4·0
Siltstone and brown, organic material	0·3
Thickness of Frenchman beds	26·3

Battle Formation

Shale, greenish grey and dark brownish grey to black, soft, bentonitic	16·3+

If the dark, lower beds of the Battle formation be assumed to have the normal thickness of these beds in this vicinity, that is, 20 feet, then the vertical interval from the top of the Whitemud formation to the base of the lignite seam is 53 feet. Pre-Frenchman erosion has here, apparently, been slight.

Outcrops in the SE. ¼ sec. 3, tp. 7, rge. 30, W. 3rd mer., on the Alberta boundary, expose 65 feet of indurated, brown to greenish brown, medium-grained, crossbedded and ripple-marked sandstone. The beds are typical of the Frenchman formation. The base of the section is 65 feet above the Whitemud-Eastend contact exposed 2 miles south of the section.

East of this section, along the west side of a small coulée, in the SW. ¼ sec. 36, tp. 6, rge. 30, typical, clean, greenish brown, medium-grained, Frenchman sandstones overlie, within a few feet, the black shale beds of the lower part of the Battle formation, and 42 feet above the contact of the Battle and Whitemud formations.

Northeast and north of the above exposures the Frenchman formation can be traced by intermittent exposures for 8 miles along Battle Creek. Numerous small exposures of these beds are scattered in secs. 4 and 5, tp. 7, rge. 29, W. 3rd mer. In the NW. ¼ sec. 8, tp. 7, rge. 29, W. 3rd mer., 50 feet of hard, crossbedded, medium-grained, grey to brown Frenchman sandstone is exposed. Other poor exposures of the sandstone continue above for an additional 98 feet around the nose of a hill, and indicate a thickness for the formation of 148 feet with neither contact exposed. Beds of the Battle and Whitemud formations underlie the sandstone and are seen nearby in contact with the Frenchman beds. Slumped exposures show that the base of the sandstone is in contact with the lower black shale beds of the Battle formation, and from 9 to 20 feet above its contact with the Whitemud. This contact is estimated to lie some 25 feet below the 148-foot section of sandstone referred to above, and its contact with the Battle formation would, therefore, lie only a few feet below the base of the 50-foot section exposed, indicating a possible thickness for the formation of 150 feet.

In the NW. ¼ sec. 17, tp. 7, rge. 29, W. 3rd mer., 72 feet of Frenchman sandstone beds are exposed at intervals above the Battle and Whitemud formations. The upper beds of the formation, consisting of hard, crossbedded, medium-grained sandstone, are exposed in the SW. ¼ sec. 19, tp. 7, rge. 29, W. 3rd mer.

A thick section of hard Frenchman beds is exposed along the northeast side of a narrow ridge in the NW. ¼ sec. 2, tp. 8, rge. 30, on the east side of Battle Creek. The section is as follows:

Frenchman Formation	Thickness Feet
Sandstone, hard, brown; concretionary at base and crossbedded at top; medium- to coarse-grained	26·0+

Frenchman Formation—Concluded	Thickness Feet
Sandstone, brown and light grey, coarsely bedded and coarsely crossbedded, compacted, medium- to coarse-grained; numerous limonitic silt laminæ	27·0
Sandstone, greenish brown, fine- to medium-grained	5·0
	58·0
Battle Formation	
Shale, olive-green, bentonitic	3·0
Shale, light brown, siliceous	0·5
Shale, dark brown to black, bentonitic	15·5

The Frenchman formation is exposed in a series of outcrops over a distance of 4 miles along the southwest slopes of Old Man On His Back Plateau. These outcrops extend from sec. 10, tp. 3, rge. 25, to sec. 36, tp. 2, rge. 25. In the northeast corner of sec. 34, tp. 2, rge. 25, pre-Frenchman erosion has cut down nearly to the top of the Bearpaw formation, and Frenchman beds here have a thickness of more than 114 feet. The upper beds and contact have been removed by later erosion.

The section in the SE. ¼ sec. 10, tp. 3, rge. 25, is as follows:

Frenchman Formation	Thickness Feet
Sandstone, hard, brown, medium-grained	5·0+
Sandstone, coarse-grained, crossbedded, brown and greenish brown; some hard layers	28·6
Eastend Formation	
Sand, very fine-grained, finely bedded, yellowish brown to brown; thin lenses of grey shale at upper contact	18·0

A mile and a half southeast of the above, in the NE. ¼ sec. 34, tp. 2, rge. 25, is the following section:

Frenchman Formation	Thickness Feet
Sandstone, hard, crossbedded, brown, medium-grained	31·4+
Sandstone, greenish brown to brown, compacted, medium- to coarse-grained at base, finer at top; thin, hard laminæ	17·0
Sandstone, greenish brown, medium-grained; occasional concretionary layers	60·0
Sandstone, hard, thinly bedded, medium-grained at base to fine- to medium-grained at top, brownish grey weathering, crossbedded, grey	5·0
Shale, dark grey, irregularly bedded, lenticular, interbedded with rusty iron-bearing silt, and fine sand; whole zone very rusty weathering	0·6
Total thickness	114·0
Eastend Formation	
Sandstone, very fine, thinly bedded, yellowish buff	6·0+

However, pre-Frenchman erosion has not everywhere cut so deeply into the underlying sediments in this vicinity. At places the Frenchman beds are resting upon lower beds of the Whitemud formation, and 12 to 15 feet of white, kaolinized, feldspathic sandstones were observed in some of the sections. The lower contact of the Frenchman formation has a vertical stratigraphic range of at least 65 feet. Siltstone conglomerate lenses are common in the sandstones, and at a few places are lenses of interbedded grey shales and sandstone. Immediately above a limonitic zone at the top of one of these lenses, in the SW. ¼ sec. 2, tp. 3, rge. 25, a prolific bone bed was found, and the *Triceratops* fauna was

identified from a collection made at this locality. These beds lie 40 feet stratigraphically above the Eastend-Whitemud contact.

The 60 feet of beds lying between the dark beds of the Battle formation and the lignite seam at the base of the Ravenscrag formation at Boundary Plateau in the southeast corner of the map-area are not well exposed. Pits, however, revealed the presence of some of the typical clean, greenish brown, medium-grained Frenchman sandstone, indicating that this formation is represented here. The top of these beds is 84 feet above the top of the Whitemud formation.

Palæontology. The Frenchman beds are noted for their widespread content of vertebrate fossils, chiefly dinosaur remains. As early as 1875 Dawson found the first dinosaur bones, and collections have been greatly increased through the subsequent investigations of McConnell (1885), Rose (1916), and Sternberg (1924). These fossils have been identified by C. W. Gilmore and C. M. Sternberg, and include the following (Fraser *et al.*, 1935, p. 42): *Lepisosteus occidentalis* Leidy, *Myladaphus bipartitus* Cope, *Acapherpeton tectum* Cope, *Baena hatcheri* Hay, *Baena longicauda* Russell, *Thescelus* sp., *Igaunavus* sp., *Lancesaurus hatcheri* Gilmore, *Thespesius saskatchewanenis* Sternberg, *Thescelosaurus neglectus* Gilmore, *Triceratops prorsus* Marsh, *Triceratops* sp., *Ornithomimus* sp., and *Crococylus* sp.

Specimens collected by the writer from the uppermost of the exposed beds of the Frenchman formation on Old Man On His Back Plateau, in the SW. ¼ sec. 2, tp. 3, rge. 25, were identified by Sternberg as the distal half of the humerus of *Triceratops* sp. and part of a left denture of a small carnivorous dinosaur, as yet undescribed but thought by Sternberg to be a descendant of *Macrophalangia* or *Stenonychosaurus*.

A flora has also been collected by Sternberg and others from Frenchman beds (former Lower Ravenscrag) east of the Cypress Lake area, and identified by E. W. Berry (Fraser *et al.*, 1935, p. 43).

Age and Correlation. The age of the Frenchman beds is established by both the vertebrate fauna and the flora as very late Upper Cretaceous. This evidence has been described and discussed by McLearn and others (Fraser *et al.*, 1935, p. 43), who correlate these beds with the Hell Creek or lower part of the Lance formation of northeastern Montana, that is, the beds that include the last dinosaur or *Triceratops* fauna, but not with the overlying lignite beds.

Russell (Russell and Landes, 1940, pp. 93-95) states that the Frenchman (former Lower Ravenscrag) and McLearn's grey facies of the Ravenscrag (former Upper Ravenscrag) are absent at the west end of the Cypress Hills in Alberta, and concludes that the Ravenscrag of Alberta represents only the buff facies of the Saskatchewan Ravenscrag. Though the writer has not studied this part of the section at the west end of the Cypress Hills in detail, massive sandstones having the lithology of the Frenchman beds are recognized overlying the Battle formation along Medicine Lodge Coulée and south of Elkwater Lake in Alberta. Russell measured and described the section on the road south of Elkwater Lake, in secs. 13, 14, and 24, tp. 8, rge. 3, W. 4th mer., as follows:

	Thickness Feet
Silt, clayey, light buff	2·0
Clay, dark grey	0·2
Clay, light grey	5·0
Clay, silty, light greenish grey	1·5
Concealed	92·0
Clay, silty, alternating light buff and brick-red (burned carbonaceous beds?)	4·0

	Thickness Feet
Concealed	267·0
Sandstone, massive, soft, fine-grained, brownish buff, with large, rounded, hard, crossbedded, indurated masses, and irregular, brown, clay fragments	60·0
Sandstone, soft, highly crossbedded, banded reddish brown, brown, and grey, becoming coarse below	30·0
Concealed	41·0
Sandstone, soft, medium-grained, crossbedded, grey-buff, grey-brown, and brown, light weathering, with beds up to 1·5 feet thick of clay pellets; some small ironstone concretions	66·0
(Ravenscrag-Eastend unconformity)	
Clay, light purplish grey, slightly carbonaceous	1·9

The massive beds in the lower 197 feet above the unconformity reflect typical Frenchman sedimentation, and are lithologically similar to the beds of the Frenchman formation, whereas the thinly bedded character of the sediments at the top of the section is typical of the Ravenscrag (former Upper Ravenscrag) of the Cypress Lake area. This interpretation of the above section is supported by the evidence already discussed for the thickening of the Frenchman formation from east to west across the Cypress Lake area, reaching a thickness of 150 feet near the Alberta boundary (*See* Figure 2). As will be discussed subsequently, the grey facies of the Ravenscrag formation has been traced across the Cypress Lake area to Adams Creek near the Alberta boundary where it has a thickness of 150 feet. Only 20 feet of the overlying buff facies is present there beneath the unconformable Cypress Hills conglomerate. It would appear, therefore, that the Frenchman beds have continued to thicken westward until at Elkwater Lake, Alberta, they have attained a thickness of approximately 200 feet (*See* Figure 2). The grey facies of the Ravenscrag would overlie these beds, and in the above section would occur in the 267 feet of concealed beds. In fact, the beds at the top of the section could belong to this facies. It is possible that the overlying buff facies of the Ravenscrag has, at places, been almost completely removed by erosion preceding the deposition of the Cypress Hills conglomerate at the western end of the Cypress Hills.

The correlation of the Frenchman beds westward across the Sweetgrass arch is yet uncertain, because of the absence of palæontological evidence of the age of the beds there.

CHAPTER V

TERTIARY STRATIGRAPHY

RAVENSCRAG FORMATION

The name Ravenscrag is here redefined to include only those strata that were formerly described as Upper Ravenscrag (McLearn, 1929, p. 40; F. J. Fraser *et al.*, 1935, p. 39). The desirability of assigning a formational name to the beds formerly called "Lower Ravenscrag" necessitated, also, renaming those comprising the former Upper Ravenscrag, and as the name "Ravenscrag" had become well entrenched in geological literature since it was first proposed it seemed preferable to redefine it than to adopt a new name.

The Ravenscrag formation here designates the thick, non-marine series of finely bedded and interbedded, grey and buff shales, silts, fine sands, lignitic laminæ, and coal seams that overlie the Frenchman formation and are overlain unconformably by the Cypress Hills formation. The lower beds have a grey aspect, whereas the upper beds are buff, due to the presence of limonite. McConnell recognized this colour distinction, and, more recently, the respective assemblages have been referred to as the "grey facies" and the "buff facies" (F. J. Fraser *et al.*, 1935, p. 45). The two show gradational and, stratigraphically, quite irregular contacts.

N. B. Davis (1918, pp. 10, 11) first applied the name "Ravenscrag" to the 279 feet of beds comprising the upper seven divisions of McConnell's (1885, p. 28) section of the Laramie, on Ravenscrag Butte, 3½ miles east of Ravenscrag. However, the 36 feet of beds comprising the lowest two of these divisions (6 and 7) are included by the present writer in the Frenchman formation, and division 5, consisting of 3 feet of lignite, is the coal seam locally known as the No. 1 seam, and marks the base of the Ravenscrag formation in this vicinity.

East of the map-area the beds stratigraphically equivalent to those comprising this formation have been variously designated as: the upper part of the Lignite Tertiary, by Dawson (1875); the upper part of the Laramie, by McConnell (1885); the Fort Union, by Rose (1916); the Ravenscrag and Estevan, by Davis (1918); and the Upper Ravenscrag, by McLearn and others (McLearn, 1929, p. 40; F. J. Fraser *et al.*, 1935).

Distribution. Within the map-area outcrops of the Ravenscrag formation are restricted to the higher slopes of the Cypress Hills proper and along Frenchman River Valley. The best exposures are along Frenchman River east of Ravenscrag, and along Adams Creek in tp. 7, rge. 28. Other exposures occur along Concrete Coulée and Conglomerate Creek, in tp. 7, rge. 23; along the upper tributaries of Farewell Creek, in tps. 7 and 8, rge. 24; along the upper end of Lonepine Creek, in tp. 8, rge. 26; on both the east and west slopes of "The Gap"; along the upper end of Battle Creek and its tributaries, in tps. 7 and 8, rges. 29 and 30; and in the north part of tp. 6, rge. 30. Scattered outcrops occur along the north slopes of the hills in the northern part of tp. 8, rges. 29 and 30; in the north half of tp. 9, rges. 23, 24, and 25; and in the south part of tp. 10, rge. 23. No exposures of this formation were found in the map-area at any point distant from the main region of the Cypress Hills.

Though restricted within the map-area, Ravenscrag beds have a wide distribution farther east, and westward they have been traced 20 miles into Alberta to the Head of the Mountain area at the west end of the Cypress Hills.

Lithology and Contacts. The Ravenscrag formation consists of a monotonous series of grey to buff weathering, uniformly finely bedded and interbedded, soft, grey to brownish grey clays and shales and grey and buff to light brown, fine sands, silts, argillaceous sands, and sandy shales. Lignite seams are plentiful and occur at various horizons, though in this area they are more numerous and thicker in the lower 125 feet of the formation near Ravenscrag, whereas in the western part of the area, along Adams Creek, they are more numerous in the lower 50 feet. A number of the seams have been mined, and though the coal is of inferior grade it has been used for local domestic purposes. In addition to the thicker seams, thin laminæ of lignitic and organic plant material are abundant. Fossil tap roots are common. Bentonite beds and brown weathering clay ironstone concretionary layers, as well as hard sandstone and siltstone concretionary layers, are present, though in general the Ravenscrag beds are poorly cemented. Crossbedding and local channelling and filling were observed at places.

The outstanding feature of the formation appears to be the generally constant lithological character exhibited throughout entire sections of this relatively thick series of non-marine sediments, in contrast with the variation in character of the sediments comprising the underlying formations. It suggests a stabilization of conditions of deposition for a somewhat prolonged period. The sediments are uniformly fine-grained, and the contained fauna and flora indicate a nonmarine, alluvial plain environment (F. J. Fraser *et al.*, 1935, p. 45).

The lower contact of the formation with underlying Frenchman beds has been discussed under that formation. It is drawn at the base of a prominent lignite member that is not everywhere at the same horizon, but rises, stratigraphically, westward across the Cypress Lake map-area.

The upper contact is at an erosional unconformity, above which lie the sandstones and conglomerates of the Cypress Hills formation. The erosion surface is highly irregular, and at places, particularly along the flanks of the hills, is cut down through pre-Cypress Hills formations to the Bearpaw, and evidently represents a relatively long period of widespread erosion.

Thickness. The thickness of the Ravenscrag formation varies from place to place, as the lower contact is not drawn everywhere at the same stratigraphic horizon, and as the upper contact is an erosional one. In many parts of the map-area the formation has been removed by erosion prior to deposition of succeeding Cypress Hills beds. A maximum thickness of 227 feet was measured in a section on Ravenscrag Butte, in the NE. ¼ sec. 26, tp. 6, rge. 23. The lower 125 feet of this section comprises the "grey facies". Along Adams Creek, in the NE. ¼ sec. 17, tp. 7, rge. 28, the beds total 170 feet, and the upper contact with the Cypress Hills conglomerate is exposed to the north at an elevation of 25 feet above the top of the section. Approximately 150 feet of these beds belong to the "grey facies".

Detailed Description. The type area for the Ravenscrag formation is Ravenscrag Butte, 4 miles east of Ravenscrag on the north side of Frenchman River. Several sections were measured, of which the following is a representative composite section in the west half of sec. 26, tp. 6, rge. 23:

	Thickness Feet
Cypress Hills Formation	
Conglomerate, cemented and coarse; grey, hard sandstone	10·0+
Ravenscrag Formation	
Sandstone, yellowish grey to buff, fine-grained; some medium-grained at base; soft, argillaceous; occasional grey shale beds; some hard sandstone and siltstone layers	40·0
Clay, light grey, plastic	2·5
Sandstone, buff, fine- to medium-grained; finely bedded; argillaceous.	29·5
Lignite, interbedded with dark grey shale	1·2
Shale, grey	4·0
Sand, buff, fine-grained; silt	5·0
Shale, yellowish grey, with interbedded silt	10·0
Sand, yellow-buff, fine-grained; silt	7·0
Shale and silt, grey	0·2
Shale, black, carbonaceous	0·1
Clay, yellowish grey to grey	2·0
Sand and silt, buff-yellow	0·7
Shale, grey	0·1
Lignite (top No. 4 seam)	1·0
Shale, dark purplish brown, fissile, hard	0·5
Lignite	3·0
Shale, dark purplish brown, hard	0·4
Lignite; few shale partings (bottom No. 4 seam)	1·8
Shale, dark grey	3·5
Lignite	0·1
Shale, grey, with interbedded buff silt	16·1
Silt, buff, with fine sand	3·0
Lignite and carbonaceous shale, No. 2 seam	0·8
Shale, dark grey	1·0
Shale, light grey weathering, grey, with two, buff, sandy, concretionary layers 0·5 foot thick; interbedded silt and sand near base	29·4
Lignite and black, carbonaceous shale	0·3
Shale, dark grey to grey, with silt and fine sand beds	10·3
Lignite, with thin shale partings, No. 2 seam	1·0
Shale, grey to dark grey, and interbedded, fine, buff sands and silts	12·0
Interbedded, buff-yellow, fine sands, silts, and grey shales	15·0
Shale, grey, with interbedded, buff, fine sand and sand	13·0
Interbedded fine sand and shale	2·6
Lignite and dark purplish brown, fissile shale (top No. 1 seam)	0·3
Organic shale, brown, fissile	4·6
Lignite	0·2
Shale, organic, brown, fissile	1·9
Lignite, with shale partings	0·8
Shale, brown, organic, fissile; with a little lignite	1·1
Lignite (bottom No. 1 seam)	1·1
Total thickness	227·1

Lateral variations in the character of both the sediments and the lignite beds are unusually marked here. The grey, plastic clay bed, 187 feet above the base of the section, can be traced for at least a mile west of the east border of the map-area. Farther west the section has been eroded. The beds of the lower 128 feet of the section weather to a general grey colour and comprise the "grey facies". The beds above are distinctly buff weathering. The section illustrates the predominance of shales and carbonaceous beds in the "grey facies" as contrasted with the predominance of sands in the overlying beds. Other outcrops of the formation in this vicinity expose only fragmentary sections that are difficult to relate stratigraphically. Such exposures occur along the south side of Frenchman River east of Ravenscrag and along both sides of the valley west of Ravenscrag to the point where the Palisade gap meets Frenchman River, in sec. 16, tp. 6, rge. 24. Sections of the Ravenscrag formation rarely exceed 50 feet, and are comprised of interbedded shale, silt, fine sand, and carbonaceous beds of the "grey facies". West from Ravenscrag Butte pre-Cypress Hills erosion

has cut increasingly deeper into the underlying beds, until, in the NE. ¼ sec. 23, tp. 6, rge. 24, on the north side of the River, and across the river from this point on Table Butte, in secs. 10 and 15, tp. 6, rge. 24, the Cypress Hills conglomerate rests directly upon beds of the Frenchman formation. A line drawn just east of these points and striking about northwest to the SE. ¼ sec. 17, tp. 8, rge. 25, marks the approximate south and southwest limits of the Ravenscrag formation after the pre-Cypress Hills erosion period and prior to the deposition of the Cypress Hills beds. Southwest of this line the Cypress Hills beds rest directly on older formations. Northeast of this line, scattered exposures of Ravenscrag beds occur, chiefly along the upper tributaries of Farewell Creek, and it is apparent that the formation thickens rapidly in this direction. In the NW. ¼ sec. 6, tp. 7, rge. 23, is the following section:

	Thickness Feet
Siltstone, concretionary layer, rusty weathering	0·5
Sand, buff, fine-grained	8·7
Clay and silt, buff; 0·3 foot of light clay about 1·5 feet above base	5·6
Shale, purplish brown	0·1
Clay and silt, buff, finely bedded	6·4
Shale, carbonaceous, brown	0·2
Shale, buff	4·9
Shale, carbonaceous, brown; lignite	0·5
Shale, buff-grey	5·1
Lignite and carbonaceous shale	0·3
Shale, buff-grey; and interbedded limonitic silt	18·8
Sand, light buff, some grey sand near base	15·0
Shale, banded, grey, with interbedded limonitic silt and some fine sand	47·3
Shale, grey; limonite laminæ, small siltstone concretions at top	2·5
Shale, carbonaceous, dark grey to black	0·8
Shale, grey	2·5
Shale, carbonaceous, black	0·1
Shale, black, carbonaceous; three beds of lignite	1·0
Shale, grey, with brown organic material	3·8
Shale, black, carbonaceous	0·7
	124·8

Frenchman Formation

Sand, brown.

The beds of the lower 100 feet of the section belong to the "grey facies", and the Cypress Hills conglomerate lies 20 to 25 feet above the top of the section.

A 70-foot section of the lower beds is poorly exposed along the banks of a creek in the northern half of sec. 28, tp. 7, rge. 24. Two lignite seams are exposed and have been mined to a limited extent. The seams are about 6 feet thick, including shale partings, and are of poor grade. Overlying the seams are 37 feet of grey shale, buff sands, and silts and carbonaceous beds. Though these are predominantly buff weathering rather than grey, the lignite seams are believed to be the equivalent of the lower carbonaceous beds of the Ravenscrag area. Near the south boundary of the section, on the east side of the creek, are small exposures of the typical olive-green, bentonitic shale and coarse, brown, clean sandstone of the Frenchman formation. These beds overlie beds believed to correspond to the carbonaceous zone of the Whitemud formation. About ½ mile farther south, on the west side of the creek, is an outcrop exposing the contact of the Whitemud and Eastend formations.

West of sec. 17, tp. 8, rge. 25, the southern boundary of the Ravenscrag formation in the Cypress Hills, at the close of the pre-Cypress Hills erosion period and prior to the deposition of the Cypress Hills formation, strikes south and west to about the SW. ¼ tp. 7, rge. 27, then westerly to about sec. 21, tp. 6, rge. 30. North of this line scattered outcrops of Ravenscrag beds occur on the

slopes around the central block of hills on which is located the Cypress Hills Provincial Park, tp. 8, rges. 26 and 27. These outcrops are mainly along Belanger Creek and in road cuts along the highway leading into the park from Maple Creek. In general the beds in these exposures belong to the "grey facies", and include numerous lignite seams. One prominent lignite seam that has been mined at a number of places outcrops along Belanger Creek in secs. 15 and 21, tp. 8, rge. 26. In the NE. ¼ sec. 15 are pits and adits on the seams exposing 14 feet of lignite with shale partings. Above the coal seam in section 21 are 12 feet of grey shale, buff sand, and lignite laminæ.

A narrow, deep valley terminates the central block of hills on its west side and trends north-northwest through secs. 3, 9, 10, and 16, tp. 8, rge. 27. Farther west is the 6-mile wide "Gap". Along the east slopes of the valley bordering "The Gap" on the east, in secs. 3, 10, and 16, tp. 8, rge. 27, are small fragmentary sections of the "grey facies". West of "The Gap" the Ravenscrag is well exposed along Adams Creek. The following section is in the NE. ¼ sec. 17, tp. 7, rge. 28, and is given here as being representative:

	Thickness Feet
Drift and reworked beds	
Sand, yellow-grey, and bright yellow silt, buff weathering	10·0
Lignite	0·1
Shale, greenish grey; little silt	4·9
Lignite, and black and brown, carbonaceous shale	0·5
Shale, greenish grey; interbedded with silt	4·0
Lignite	0·1
Sand, grading up to grey shale, with light grey concretionary layer	3·0
Shale, and lignite, carbonaceous	0·1
Sand, greenish brown, grading up to thin beds of shale at top	3·9
Lignite	0·1
Shale and silt, greenish grey	1·8
Lignite	0·2
Interbedded greenish grey silt, sand, and grey shale	4·3
Lignite and carbonaceous shale	0·1
Shale and silt, greenish grey	1·0
Siltstone, concretionary layer, grey	0·7
Interbedded grey shale and greenish grey silt	1·0
Lignite, hard, shiny	0·5
Shale, bluish green; occasional beds of black, carbonaceous shale	6·4
Sand, greenish brown, fine	1·0
Interbedded grey shale and greenish grey silt; occasional layer of dark shale	9·8
Black carbonaceous shale; little lignite	0·8
Interbedded grey shale and greenish grey silt; dark grey shale about midway	9·8
Shale and silt, finely bedded, greenish grey; thin bed of black carbonaceous shale at top	0·8
Shale, carbonaceous, black	0·6
Sand, brown, fine-grained; interbedded with greenish grey silt	1·5
Shale, bluish grey	0·8
Shale, dark grey; lignite laminæ at top	0·6
Interbedded, greenish grey, silty shale and silt; some yellow silt laminæ	8·0
Lignite	0·2
Shale, bluish green, and interbedded yellowish grey silt	1·5
Silt, and silty shale, greenish grey, finely interbedded	3·9
Shale, greenish grey and grey	2·0
Carbonaceous shale, brown to black	0·2
Shale, greenish grey	0·7
Sand, green to brownish grey, fine	1·8
Carbonaceous shale, black	0·2
Sandstone, pale greenish brown, fine, compacted	4·0
Carbonaceous shale, dark brown to black	0·9
Shale, greenish grey	0·3
Sandstone, greenish grey, massive	5·0
Shale, greenish grey	0·3

	Thickness Feet
Shale, carbonaceous, black; lignite	0·1
Shale, greenish grey, bentonitic	1·5
Shale, purplish brown	0·5
Interbedded grey shale and yellowish brown silt	6·5
Interbedded grey shale and brownish grey sand	5·0
Lignite	0·5
Shale, purplish brown	0·5
Shale, greenish grey	0·7
Sandstone, brownish grey, fine- to medium-grained, micaceous, compacted	9·0
Shale, organic, brown, fissile, grey at top	0·3
Lignite	0·2
Shale, dark greenish grey	0·7
Interbedded greenish grey shale, silt, and fine sand	4·0
Sand, brownish grey, fine- to medium-grained	4·8
Shale, grey, with interbedded greenish brown silt and siltstone, and brownish grey sand	2·1
Shale, greenish grey; thin seam lignite at top	0·8
Lignite, and dark purplish brown shale	0·5
Shale, bentonitic, olive-green	0·2
Interbedded light grey shale and greenish grey, silty shale, with few dark brown and dark grey layers	13·9
Shale, black, greenish brown and brown; lignite at top	3·8
Shale, grey and brownish grey	5·0
Sand, greenish brown, and limonitic silt	3·0
Clay, brownish grey	0·2
Lignite	0·3
Shale, dark grey	0·3
Shale, pale brown, fissile	0·1
Shale, grey	3·0
Carbonaceous shale, black; thin beds of lignite	1·9
Lignite	0·5
Shale, purplish brown	0·5
Lignite	1·4
Shale, brownish grey	0·5
Total thickness	169·7

All but the upper 10 feet of beds belong to the "grey facies". The Cypress Hills conglomerate lies about 25 feet above the top of the section. One of the characteristics of these beds is the constant and frequent repetition of the sedimentation cycle from sand to shale and then to carbonaceous beds and lignite. At places the carbonaceous beds occur at 10-foot intervals; at others the interval is less, as little as 4 and 5 feet, though the 10-foot interval seems the most common. The lignite beds at the base of the section comprise the basal carbonaceous member in this vicinity. Its base is about 75 feet above the top of the Whitemud formation. The continuous repetition of sand, shale, and carbonaceous beds is in marked contrast with the massive beds of the underlying Frenchman formation, indicating a marked change in conditions of deposition.

Though the above section is typical of many of the sections along Adams Creek, the lithology changes in the lower beds towards the south. About a mile south, in the SE. ¼ sec. 17, tp. 7, rge. 28, the lower beds are replaced by a thick section of fine- to medium-grained, coarsely crossbedded sandstone resembling Frenchman beds. That this sandstone may, indeed, represent an eastward extending lentil of a thicker Frenchman formation lying west of the map-area has been discussed under that formation. The section is as follows:

	Thickness Feet
Unconsolidated sand and gravel.	
Ravenscrag Formation	
Sand, and silt, buff to yellowish weathering, buff; some interbedded grey shale	15·0
Interbedded, grey to greenish grey shale, silt, and buff to grey sand, with black, carbonaceous and lignitic shale partings	24·5
Siltstone, concretionary, brown, ledge-forming	0·5
Interbedded, grey weathering, grey to greenish grey shale, yellow to buff silts, grey siltstone, and grey to buff fine sand; dark grey shale and lignitic laminæ	32·9
Shale, brown, organic	0·3
Sandstone, brown, fine-grained, massive	6·0
Siltstone, concretionary, pale grey	0·8
Shale, grey to greenish grey; yellow silt; laminæ of black, carbonaceous shale	3·7
Lignite, and black, carbonaceous shale	0·3
Shale, grey; some silt	3·0
Interbedded, fine-grained, brown sand, silt, and grey shale	1·5
Sand, fine-grained, brown, massive	1·5
Sandstone, conglomeratic; siltstone pebbles, ledge-forming	1·0
Sandstone, buff, fine-grained, coarsely crossbedded	23·0
Concealed	20·0
Sandstone, conglomeratic, with siltstone pebbles	1·0
Interbedded grey shales and yellow silts with some buff, fine sands	7·0
Total thickness	142·0
Frenchman Formation (?)	
Sandstone, fine- to medium-grained, coarsely crossbedded, buff to brown	54·0
Lignite, and black, carbonaceous shale	3·0+
	57·0
Frenchman Formation	
Sandstone, chiefly, coarse, brown; shale at top	67·4

Of the 199 feet of beds recorded there, only the upper 15 feet have a distinctly buff aspect. The others to the top of the thick sandstone at the base of the section belong to the "grey facies", which is, therefore, 127 feet thick, but extends to 184 feet above the lignite seam that elsewhere in the vicinity marks the base of the Ravenscrag formation. For half a mile to the south, along the east side of the creek, a few poor exposures indicate that from 12 to 15 feet of interbedded shale and sand lie between this lignite seam and the 50 feet or more of fine- to medium-grained, buff to brown sandstone that probably belongs to the Frenchman. Fossil tap roots are locally abundant in these beds. Beyond these exposures the Ravenscrag beds are almost completely eroded.

Exposures of Ravenscrag beds on the west side of Adams Creek opposite the foregoing sections are obscured by heavy vegetation, and only incomplete, scattered, short sections are available for study. Old pits mark the elevation of the basal Ravenscrag lignite seam. This lignite seam can be traced north along the sides of the valley of Adams Creek to the northern slopes of the Cypress Hills. Pits and coal dumps mark old workings on the seam in the SE. ¼ sec. 19, tp. 7, rge. 28, on the west side of the valley, and in the SW. ¼ sec. 32, tp. 7, rge. 28, on the east side. At both places caving of the pits has obscured the seam itself. The seam outcrops again on the west side of the valley in the NE. ¼ sec. 6, tp. 8, rge. 28. In the SE. ¼ sec. 1, tp. 8, rge. 29, is a series of pits on the lignite seam, here 9·5+ feet thick, with the base obscured by caving. About the middle of sec. 11, tp. 8, rge. 29, along the trail that skirts the east side of Adams Creek, are poor exposures of the basal Ravenscrag coal seam and overlying beds of the "grey facies". The interbedded grey shales, silts, buff sands, and carbon-

aceous beds here extend to 135 feet above the base of the formation and are overlain by 30 feet of distinctly buff weathering fine sands and silts. In the NE. ¼ sec. 15, tp. 8, rge. 29, on the north side of a small creek entering Adams Lake from the west, are pits and adits on the lignite seam, which is here 5·0+ feet thick, the base being obscured by caving. It is overlain by grey shales and silts.

Numerous small exposures of beds of the "grey facies" occur in the hills about Adams Lake and along the creek flowing into Adams Lake from the west. The outcrops occur mainly in the SW. ¼ sec. 21, N. ½ sec. 15, and in secs. 22 and 23, tp. 8, rge. 29. These beds consist essentially of grey shales, silts, and buff sands, with numerous lignite laminæ.

West of Adams Creek, scattered small exposures of the Ravenscrag beds occur along the upper parts of hills bordering Battle Creek Valley, and, generally, immediately below the Cypress Hills conglomerate. The most southerly outcrop is in the SE. ¼ sec. 5, tp. 7, rge. 29, W. 3rd mer. Here the greenish brown sandstones and concretionary layers of the Frenchman formation extend to an elevation of 4,088 feet. From 4,111 to 4,139 feet are distinctly grey weathering, interbedded grey and greenish grey silt, shale, and brownish grey, fine sand. Several thin laminæ of black, carbonaceous shale and lignite are present. These beds are typical of the "grey facies" of the Ravenscrag formation. The upper contact is not exposed. The beds outcrop for half a mile to the northwest.

A 60-foot section of buff sands, grey shales, silts, and lignitic laminæ outcrops in the SW. ¼ sec. 17, tp. 7, rge. 29. It is not certain whether these beds belong to the "grey" or "buff" facies. In the SW. ¼ sec. 19, tp. 7, rge. 29, is a 22-foot section of grey weathering, interbedded, greenish grey to grey shale, grey to brown silt, thin sand beds, lignite beds, and carbonaceous shale laminæ. This section is only a few feet higher than the top beds of hard, brown, medium-grained sandstone of the Frenchman formation that outcrop 250 yards north across a small valley. The beds clearly comprise the lower part of the "grey facies" of the Ravenscrag formation. The presence of thin beds of lignite and carbonaceous beds at the bottom of the section may suggest the presence of a carbonaceous zone a few feet below the exposure. The contact is estimated to be from 150 to 170 feet above the top of the Whitemud formation, as indicated by nearby outcrops of that formation. A small outcrop exposing a 15-foot section of grey weathering shales, silts, and fine sands occurs in the NE. ¼ sec. 34, tp. 7, rge. 30, on the north side of Ninemile Creek at an elevation of about 4,200 feet.

Grey shales, light brownish grey, fine sands, and silts outcrop in several short sections along the east side of Battle Creek, in the N. ½ sec. 11, tp. 8, rge. 30. The beds appear to belong to the "grey facies" and are between 4,200 and 4,280 feet in elevation.

Outcrops of the Ravenscrag formation along the northern slopes of the Cypress Hills are poor and widely separated. Exposures of fine-grained buff sands and concretionary beds totalling 20 feet are exposed in the SW. ¼ sec. 35, tp. 8, rge. 30, at an elevation of about 4,250 feet. These probably belong to the "buff facies". About 150 feet below these beds are grey weathering, grey and yellowish brown, fine sands, silts, and clay, and lignite seams. These beds have been disturbed somewhat, and may have slumped.

Aside from those exposures previously referred to along the upper end of Adams Creek, no further exposures of Ravenscrag beds were found farther east along the north slopes to tp. 9, rge. 25. Here, in the SE. ¼ sec. 20, are old workings on a lignite seam more than 4·5 feet thick with the base not exposed. It is overlain by grey clay and buff silt. The seam is about 375 feet higher than the top of the Oxarart sandstone member of the Bearpaw at its nearest exposure,

2 miles due west. The top of the Oxarart is 190 to 200 feet below the top of the Bearpaw. Allowing 75 feet for the thickness of the Eastend, 55 feet for the Whitemud, and 80 feet for both the Battle and Frenchman formations, as in the section in the NE. ¼ sec. 26, tp. 6, rge. 24, the vertical interval would be approximately 405 feet. Allowing for an east component of dip of 13 feet a mile, or a total of 26 feet, it seems evident that this coal seam corresponds, approximately, with the stratigraphic position of the basal Ravenscrag coal seam in sec. 26, tp. 6, rge. 24, locally known as the No. 2 seam.

A coal seam, reported to have a total thickness of 4·0 feet, is partly exposed in the NW. ¼ sec. 25, tp. 9, rge. 25, in the Maple Creek Indian Reserve. This seam is about 60 to 70 feet above a small exposure of Whitemud white clay in the NE. ¼ sec. 26, tp. 9, rge. 25, half a mile to the northwest. The Whitemud outcrop is in turn about 310 feet above an outcrop of the Oxarart sandstone, 1½ miles northwest, in the SW. ¼ sec. 34, tp. 9, rge. 25. The vertical intervals here again agree generally with those established for these beds along Frenchman River Valley, and indicate that the coal seam may be the basal Ravenscrag seam. Half a mile north of this exposure, some pits have been sunk on a coal seam in the SW. ¼ sec. 36, tp. 9, rge. 25. The seam there appears to be 4 feet thick, including a shale parting, but the beds have been disturbed, due either to slumping or caving, and a true section could not be measured. The coal is associated with grey shales and silts.

No further outcrops of Ravenscrag beds were encountered along the north slopes of the Cypress Hills. On Shuard Creek, in the SE. ¼ sec. 2, tp. 10, rge. 23, are outcrops of the Cypress Hills conglomerate at an elevation of approximately 3,525 feet. Half a mile northwest, in the NE. ¼ sec. 3, tp. 10, rge. 23, are exposures of buff, very fine sands and silts with some interbedded grey shales and thin lignite laminæ at 3,450 feet. As has been previously discussed, these beds occur at the calculated position for the Eastend formation, and as their lithology resembles the Eastend they are mapped as such. As the Cypress Hills conglomerate outcrops less than 75 feet above these beds, it is evident, that, as on the southern slopes of the hills, erosion preceding the deposition of the Cypress Hills formation has cut down through the Ravenscrag, Frenchman, and probably Battle formations nearly to the Whitemud formation, and possibly into it at places.

Age and Correlation. The fauna and flora of the Ravenscrag (former Upper Ravenscrag) beds have been listed and fully discussed by McLearn and others (F. J. Fraser *et al.*, 1935, pp. 51-53). The evidence favours a Paleocene age. As the present work has offered no new evidence bearing upon the age or the correlation of these beds with Montana equivalents, their conclusions will be quoted here as follows:

"As the faunal and floral evidence is inadequate, correlations on a lithological basis with some sections in the United States must be attempted . . . . In a general way the lower and grey facies of Twelvemile Lake Valley, for example, resembles the combined section of the lignite beds, the Tullock, and the Lebo shales of Eastern Montana (Russell, 1933 B). In most places there are no typical Tullock beds, unless some yellow beds correspond to them. The volcanic ash at the top of the grey facies at St. Victor resembles the Lebo member of southwestern Montana on the basis of lithology (Russell, 1933 B). It is to be noted that the facies contacts vary and the correlations are not very exact, as to limits at least. They do indicate, however, that the (Upper) Ravenscrag has a long time range in the Paleocene."

The correlation of the Frenchman and Ravenscrag beds of the Cypress Lake area with the beds at the west end of the Cypress Hills in Alberta has been discussed previously in this report in dealing with the Frenchman formation

(*See* Figure 2). There it was shown that, contrary to Russell's interpretation, the evidence indicates that the Frenchman beds (former Lower Ravenscrag) continue westward and thicken in that direction, and that there is no denfiite evidence to indicate that the grey facies of the Ravenscrag beds is not present there between the Frenchman formation and the Cypress Hills conglomerate.

The Ravenscrag beds, like those of the Frenchman formation, represent relatively stable conditions of sedimentation, permitting the accumulation of a comparatively thick series of non-marine sediments under an alluvial plain environment during a period of aggradation above sea-level.

CYPRESS HILLS FORMATION

The Cypress Hills formation, comprised chiefly of hard, cemented, coarse conglomerates and interbedded, hard, grey, coarse sandstone, is quite distinctive lithologically (*See* Plate IV B). The beds were first recognized and described by McConnell (1885).

The type section of the formation is just east of the map-area on Bone Creek, which flows eastward into Swift Current Creek. Here McConnell described a series consisting of pebble and clay conglomerates; occasional beds of loose gravel; hard and soft, generally coarse-grained, crossbedded sandstones; dark-coloured clays; small beds of impure limestone and whitish marls, and estimated to total about 500 feet in thickness. Subsequent work by McLearn (Fraser *et al.*, 1935, p. 56) indicates, however, that the thickness is only 125 feet.

Distribution. The Cypress Hills formation underlies the summits and parts of both the north and south flanks of the Cypress Hills. Outcrops are distributed around the dissected margin of the broad upland at the east side of the map-area, and the formation is well exposed at the summits of the hills along Frenchman River Valley and its tributaries from Ravenscrag Butte to Cypress Lake. Numerous outcrops occur along the north side of Cypress Lake and, west of the lake, along the northern slopes of the valley of Battle Creek to sec. 34, tp. 5, rge. 28. The central upland, in tp. 8, rges. 26 and 27, is fringed by outcrops of Cypress Hills conglomerate, as are the uplands west of "The Gap" and those enclosing the valley of Battle Creek and its tributaries at the west side of the map-area. Small outcrops of these beds occur in secs. 16, 17, and 21, tp. 6, rge. 29. Other outcrops occur along the east side of a coulée in secs. 18 and 19, tp. 5, rge. 23, W. 3rd mer.

Lithology. The most prominent member of the Cypress Hills formation is the conglomerate. It commonly outcrops as thick ledges fringing the crests of the hills, and, in general, consists of well-rounded, ovoid boulders, and subangular to rounded pebbles, cobbles, and boulders in a hard, grey, highly calcareous, coarse sandstone matrix (*See* Plate IV B). The boulders are as much as 8 inches in maximum diameter, but average considerably less. The larger cobbles and boulders consist chiefly of quartzite; many are white or light brown; others are banded and varicoloured. The pebbles and smaller cobbles are composed of a great variety of rocks, chiefly quartzite, but including also andesite, feldspar porphyries, volcanic types, conglomerate, coarse-grained, acidic, intrusive rocks, granite-gneiss, and vein quartz. The larger boulders carry numerous, semicircular, chatter or percussion marks.

Most of the conglomerate is well cemented and forms resistant ledges (*See* Plate IV B). In places poorly consolidated gravels are interbedded with it, as in the SW. $\frac{1}{4}$ sec. 26, tp. 7, rge. 30.

Siltstone breccias are, in places, associated with the conglomerates, as in the NE. $\frac{1}{4}$ sec. 22, tp. 6, rge. 24, on the north side of Frenchman River, and along

a coulée extending north from the river. There both grey and brown, hard sandstones contain numerous angular and subangular fragments of buff and grey siltstone and shale, in addition to sparsely scattered quartzite pebbles. These beds pass upwards into the typical coarse quartzite conglomerate.

The grey, coarse, calcareous sandstone comprising the matrix of the conglomerate forms beds between layers of conglomerates that pass laterally into the sandstone, which is generally coarsely crossbedded and thickly bedded. Buff, medium-grained sandstones occur with the conglomerates in places. In general the beds show great lateral variation.

Marls are commonly associated with the conglomerates and sandstones, particularly along Frenchman River Valley, as in the SW. ¼ sec. 27, tp. 6, rge. 25, and on the north edge of Table Butte, in the NW. ¼ sec. 15, tp. 6, rge. 24. West of Cypress Lake, on the north side of Battle Creek, in the NW. ¼ sec. 34, tp. 5, rge. 28, 20 feet of marl and marly sands overlie the coarse conglomerate.

Contacts. The upper beds of the Cypress Hills formation have everywhere been eroded; the lower contact is unconformable. This unconformity is one of considerable magnitude and extent. Evidence from the Cypress Lake map-area indicates that at least 700 feet of sediments have been removed during the erosion interval and prior to the deposition of the basal conglomerates. The plane of the unconformity rises stratigraphically from west to east.

In the higher parts of the hills the formation is in contact with the "buff facies" of the Ravenscrag formation, as along Battle Creek, in tps. 7 and 8, rges. 29 and 30, where the elevation of the contact is from 4,200 to more than 4,400 feet; along Adams Creek, in tp. 7, rge. 28, and tp. 8, rge. 29, at elevations of 4,200 feet and higher; along the east side of "The Gap" in tp. 8, rge. 27; along tributaries of Farewell Creek, in tps. 7 and 8, rge. 24; along the headwaters of Piapot Creek, in the Indian Reserve in the NW. ¼ tp. 9, rge. 25, where the contact is at an elevation between 3,700 and 3,850 feet; along Concrete Creek, in tp. 7, rge. 23, where the contact is at 3,600 to 3,700 feet; and on Ravenscrag Butte, where the contact is at an elevation of 3,670 to 3,680 feet. Though the Cypress Hills conglomerate probably lies upon the "grey facies" of the Ravenscrag in many places lower on the slopes of the hills, it was found in contact with this facies at only one point, on the north side of Harris Creek, in the NE. ¼ sec. 15, tp. 8, rge. 29, and here there is a possibility that the blocks of conglomerate may have slumped from originally higher positions.

The Cypress Hills beds lie directly upon beds of the Frenchman formation at many places along the southern slopes of the hills. In the NW. ¼ sec. 23, tp. 6, rge. 24, on the north side of Frenchman River, the Cypress Hills conglomerate rests on coarse-grained Frenchman sandstone at about 35 feet above the base of the formation, and at an elevation of 3,535 feet. Farther west pre-Cypress Hills erosion has cut into the Whitemud formation, and at ¼ mile west the Cypress Hills conglomerate rests directly on the coarse white sandstone of the No. 1 zone of the Whitemud formation at 3,450 feet. Still farther west the plane of the unconformity rises slightly, so that in the NW. ¼ sec. 22, tp. 6, rge. 24, the conglomerate again rests upon beds of the Frenchman formation, at 3,460 feet. The pre-Frenchman erosion has here cut down through the Whitemud formation, and Frenchman beds rest directly upon the Eastend.

The unconformity is well exposed along the west and north sides of Table Butte on the south side of Frenchman River, in secs. 10 and 15, tp. 6, rge. 24, at elevations from 3,460 to 3,470 feet. At places nearby the Cypress Hills conglomerate rests on sections less than 12 feet thick of brown Frenchman sandstone, and these beds in turn are in unconformable contact with beds of the Whitemud formation. Both unconformities are well exposed in these sections. At other

nearby places the Cypress Hills conglomerate rests directly upon beds of the Whitemud formation.

In addition to those localities mentioned above, the Cypress Hills beds rest unconformably upon the beds of the Whitemud formation along the west side of a coulée in the NE. ¼ sec. 28, tp. 6, rge. 24, and again on the south side of a coulée in the NW. ¼ sec. 11, tp. 6, rge. 24.

In the eastern part of the map-area pre-Cypress Hills erosion has removed beds down to the Eastend formation at numerous places along the southern slopes of the hills, and at one place at least on the northern slopes. This condition is well exposed at numerous points along the north side of Frenchman River, from the SE. ¼ sec. 28, to the NE. ¼ sec. 29, tp. 6, rge. 24, where the contact is at an elevation of 3,450 to 3,460 feet. This is also the condition on the south side of Frenchman River, in the NW. ¼ sec. 20, tp. 6, rge. 24, at an elevation of 3,420 to 3,440 feet; on the north side of a coulée at the northeast corner of sec. 10, tp. 6, rge. 24; and along the east side of a coulée in the NE. ¼ sec. 18, tp. 5, rge. 23, at an elevation of 3,375 feet. In secs. 7 and 8, tp. 7, rge. 24, on the south side of the west branch of Farewell Creek, the Cypress Hills conglomerate outcrops at an elevation of about 3,513 to 3,535 feet, and rests upon very fine, grey to buff, some light grey, sand and silt. These beds appear to represent a transition from Eastend to Whitemud. On the east side of Shuard Creek, on the north side of Cypress Hills, in the SE. ¼ sec. 3, tp. 10, rge. 23, are outcrops of buff, very fine-grained sands and silts, with occasional lignite laminæ and grey shale. These beds are much too low to belong to the "buff facies" of the Ravenscrag, and, as they occur but little lower in elevation than the point at which the Eastend should occur, they are considered to be Eastend beds. Seventy-five feet above these beds are others of the coarse conglomerate of the Cypress Hills formation. Though the intervening beds are not exposed, the conglomerate must be in contact with beds of the Whitemud or older formations. Its elevation is 3,525 feet.

Coarse conglomerates may be seen resting directly upon Bearpaw beds at many places along the southern slopes of the hills west of Farewell Creek. The conglomerate, overlain by light-coloured marls, outcrops as a series of ledges along the northeast side of Frenchman River, in secs. 22, 27, 28, and 33, tp. 6, rge. 25, at elevations of from 3,409 to 3,422 feet. Below the conglomerate are scattered outcrops of the dark grey shale of the Bearpaw formation. In the NE. ¼ sec. 28 the base of the conglomerate, at an elevation of 3,416 feet, is only 32 feet above a 38-foot section of the dark grey marine Bearpaw shales, and some 150 feet above the Belanger member of the Bearpaw. Due south of these exposures, on the south side of Frenchman River, along a ravine in the SE. ¼ sec. 16, tp. 6, rge. 25, are outcrops of the coarse, cemented conglomerates at an approximate elevation of 3,450 to 3,470 feet. Dark grey marine shales are exposed on hills 200 yards to the east, and at elevations as high as 3,440 feet. On the east side of Belanger Creek, at its junction with Frenchman River, in the SW. ¼ sec. 30, tp. 6, rge. 25, the coarse, cemented conglomerate and grey sandstone outcrop at an elevation of 3,431 feet. Below this exposure, from 3,371 to 3,291 feet, are dark brownish grey and dark grey marine shales. Lower on the slope, at an elevation of 3,266 feet, are the concretionary layer and brown shaly sandstone of the Belanger member of the Bearpaw. Farther upstream, in the NW. ¼ sec. 30, tp. 6, rge. 25, are exposures of the conglomerate at an elevation of 3,442 feet. On the east side of Sucker Creek, in the NW. ¼ sec. 11, tp. 7, rge. 26, is a 10-foot section of coarse, cemented conglomerates at an elevation of approximately 3,550 feet.

Along the north shores of Cypress Lake the coarse conglomerate outcrops at places as a thin ledge at the edge of the hill tops. Though contacts are not

generally exposed, dark grey marine shales outcrop at various elevations on the slopes below them. In the SE. ¼ sec. 28, tp. 6, rge. 26, the conglomerate outcrops at an elevation of 3,460 feet. Below it are the dark grey marine shales, and at an elevation of 3,380 feet is the fossiliferous concretionary layer of the Belanger member of the Bearpaw formation.

West of Cypress Lake, in the SW. ¼ sec. 13, tp. 6, rge. 28, on the south side of a coulée, are outcrops of the coarse, cemented conglomerate at an elevation of 3,447 feet. From 24 to 44 feet below it is dark Bearpaw shale, and beneath the shale, to 67 feet, is the Oxarart sandstone member of the Bearpaw formation. On the north side of Battle Creek, in the NE. ¼ sec. 34, tp. 5, rge. 28, is an exposure 50 feet long of coarse, cemented conglomerates at an elevation of approximately 3,260 feet. As this outcrop is more than 125 feet lower than the outcrops of the Oxarart member 1½ miles to the north, it must be concluded that the outcrop overlies marine Bearpaw shale stratigraphically lower than the Oxarart, and at this place it represents the lowest stratigraphic horizon known to be reached by pre-Cypress Hills erosion.

West of Battle Creek, in the NW. ¼ sec. 16, tp. 6, rge. 29, the coarse cemented conglomerate outcrops at 3,648 feet, only 18 feet above the Belanger member and 87 feet above the Oxarart member of the Bearpaw. Other outcrops of the conglomerate occur along the north side of a coulée in the SE. ¼ sec. 17, tp. 6, rge. 29, at an elevation of 3,660 feet and 130 feet above the top of the Oxarart sandstone.

It is evident, from the above, that the erosional contact marking the base of the Cypress Hills conglomerate at the east boundary of the map-area rises from a structural low of 3,375 feet in tp. 5, to at least 3,680 feet on Ravenscrag Butte, and, though not exposed, is probably higher to the north in tp. 8, dropping in elevation again, on the north side of the hills, in tp. 10, to 3,525 feet. Across this north-south section the conglomerate rests upon Eastend beds, in tp. 5; the "buff facies" of the Ravenscrag formation, on Ravenscrag Butte; and again on Eastend or Whitemud beds in tp. 10. There is, therefore, both a structural and stratigraphic relief of more than 300 feet across the section. Similarly, at the western boundary of the map-area, the contact rises from 3,648 feet, in tp. 6, to more than 4,200 feet, in tps. 7 and 8. This comprises a structural relief of more than 550 feet, and a stratigraphic relief extending from the Oxarart member of the Bearpaw to the "grey facies" of the Ravenscrag formation, or about 600 to 700 feet. The conglomerates have been eroded extensively on the north flank of the hills, at the west side of the map-area. It is not possible, therefore, to determine what the relative stratigraphic position and elevation of the contact in this part of the area was. This is unfortunate, as the foregoing data from the east side of the map-area indicate a topographic feature that may have existed in the area occupied by the Cypress Hills prior to deposition of the Cypress Hills formation. In the NE. ¼ sec. 34, tp. 15, rge. 13, W. 3rd mer., northeast of Swift Current, the Cypress Hills conglomerate rests on Bearpaw beds (Russell and Wickenden, 1933, p. 54).

Thickness. The upper part of the Cypress Hills formation has everywhere been eroded, and at no place in the map-area is a continuous section of more than 50 feet of beds exposed. It is possible, however, to arrive at some idea of the minimum aggregate thickness of the remaining part of the formation. For example, in the section along the eastern boundary of the map-area, already discussed, there is a structural and stratigraphic relief at the lower erosional contact of more than 300 feet. In view of the almost horizontal attitude of the underlying beds it seems evident that the Cypress Hills formation along this section has a thickness in excess of 300 feet. Similarly, along the western boundary of the map-area it may be inferred that the formation has a total thickness of more than 550 feet.

Palæontology. A large fauna has been collected from the Cypress Hills beds by McConnell and by subsequent investigators. Williams and Dyer (1930, p. 71) published a list of this fauna. The list was revised and added to by Russell (1934). McConnell's collection was studied by E. D. Cope, who classified the beds containing the fauna as of White River or Oligocene age (McConnell, 1885, Appendix I). In referring to the beds in his report and on his map as "Miocene" McConnell used the term in the sense of including Oligocene. The fauna was studied subsequently by L. M. Lambe (1908) and, later, by Russell (Russell, 1934; Russell and Landes, 1941, p. 97).

Very few fossils were found in the Cypress Hills beds within the Cypress Lake map-area, though every outcrop was carefully inspected, particularly those occurring at the lower stratigraphic horizons. A mammal tooth and a number of sand casts of shells of the genus *Viviparus* were found in the NE. $\frac{1}{4}$ sec. 21, tp. 9, rge. 24, on the northwest side of a deep coulée and at an elevation of about 3,840 feet. The fossils were found 5 feet above the base of a 16-foot section of buff sandstone containing shale and silt pebble lenses, and overlain by 15 feet of typical Cypress Hills conglomerate. Russell (personal communication, May 18, 1942) has tentatively identified the tooth as the third upper left pre-molar of a carnivore close to the genus *Daphoenus*, a primitive group of dogs confined to the Lower and Middle Oligocene, though he states the tooth is shorter and more robust than is usual for this genus.

Age and Correlation. On the basis of the vertebrate fossils found in the Cypress Hills formation, Russell (Russell and Landes, 1941, p. 97) has correlated these beds with the lower part of the White River formation of the Black Hills region of South Dakota, and has placed their age as early Chadron and post-Duchesne River, or very early Oligocene. However, it is probably unwise to assume that all the conglomerates are of this age, in view of the discovery of the Upper Eocene fauna in the lithologically similar beds, the Swift Current beds, southeast of Swift Current (Russell and Wickenden, 1933). If Russell's tentative identification of the tooth of the genus *Daphoenus* proves correct, then between the locality at which this tooth was found and the fossiliferous beds at the type section in Bone Coulée, 12 miles to the east and approximately 300 feet lower in elevation, it may be stated that, allowing for an eastward dip of 13 feet a mile which, as discussed subsequently, is the average for these beds, there is at least 150 feet of beds whose age extends from very early Oligocene to not later than Middle Oligocene.

The Swift Current beds, referred to above, were first described and named by Russell and Wickenden (1933). The type section is in tp. 15, rge. 12, W. 3rd mer., about 7 miles southeast of Swift Current. There a 52-foot section of hard and soft sandstones with coarse conglomerate at the base and hard conglomeratic sandstone at the top overlies, unconformably, very fine sandstone beds believed to be either Eastend or an arenaceous member of the Bearpaw. An Upper Eocene or Uinta fauna was collected from the hard conglomerate sandstone at the top of the section. Seven miles to the northwest the basal conglomerate rests on Bearpaw shale.

The fossil horizon of the Swift Current beds is at an elevation of about 2,650 feet, or about 900 feet lower (Russell and Wickenden, 1933, p. 54) than the basal beds of the Oligocene, Cypress Hills beds at their type section. Evidence is presented to suggest that the Swift Current beds pass upward continuously into the Oligocene, Cypress Hills beds that outcrop at higher elevations around the flanks of, and over, the Cypress Hills.

It is possible that the coarse, hard, quartzite conglomerates and grey sandstones along the south flanks of the Cypress Hills west of Cypress Lake, which overlie beds stratigraphically 250 feet below the top of the Bearpaw formation

and at least some 700 feet lower than the Cypress Hills conglomerates overlying the buff facies of the Ravenscrag formation 10 to 12 miles to the north, may, like those at Swift Current, be of pre-Oligocene age. Though the outcrops were carefully examined for fossil teeth or other remains, none was found.

Lithologically similar beds cap Hand Hills, in tps. 29 and 30, rge. 17, W. 3rd mer., just east of Drumheller, and on the Swan River Plateau south of Lesser Slave Lake, Alberta. W. C. Alden (1924, p. 386, and 1932) found Oligocene deposits similar in character to these distributed over a wide area in Montana, the Dakotas, and Wyoming. The surfaces of these he correlated into a plain that he named the Cypress Plain.

Origin. The Cypress Hills fauna indicates a freshwater, fluviatile environment. Apparently the beds were deposited on a broad, aggrading, alluvial or piedmont plain extending eastwards from the Rocky Mountains. The imbrication of the pebbles indicates deposition from, generally, eastward-flowing rivers. The size of the pebbles, cobbles, and boulders increases in general westward. In Saskatchewan, east of the map-area, they are 6 inches or less in diameter (Fraser *et al.*, 1935, p. 56); in the present map-area they are as much as 8 inches across; and at the west end of the Cypress Hills, in Alberta, boulders a foot in diameter are not uncommon. The lithological similarity of the quartzite comprising most of the pebbles to quartzites in the Rocky Mountains has been pointed out (McConnell, 1885).

Deposition commenced in Upper Eocene time with the Swift Current beds, and appears to have been continuous into Lower Oligocene time, filling up the basins and valleys and ultimately covering the uplands. This view has been expressed by Russell and Wickenden (1933). The presence of remnants of coarse conglomerates resting upon beds of older formations having a stratigraphic range of more than 600 feet may imply that the complete section of the Cypress Hills formation originally consisted of an alternating series of conglomerate lenses and soft, easily eroded beds of marl, sand, silt, and clay that have in large part been subsequently eroded.

As the upper surface of the formation is an erosion surface, little can be deduced from the present form of this surface as to the direction of flow of the rivers that deposited the beds comprising the formation. Attempts have been made to determine the former height of the Rocky Mountains, by calculating and plotting the gradients required to produce currents sufficiently strong to transport the large boulders 200 miles east of these mountains (Lawson, 1925). However, it should be pointed out that, just as the Cypress Hills conglomerates were subsequently reworked to produce the younger, widespread gravel deposits of Wood Mountain Plateau east of the Cypress Hills, so the materials comprising the Cypress Hills beds may originally have been deposited much closer to the Rocky Mountains, and subsequently uplifted, reworked, and transported, in early Oligocene time, to their present, temporary resting place.

CHAPTER VI

SANDSTONE DYKES

Sandstone dykes are very numerous and widespread along both the north and south slopes of the Cypress Hills, and occur at many different stratigraphic horizons in the Bearpaw formation. They are similar to those previously described from southeastern Alberta by Williams and Phemister (1927), Williams and Dyer (1930), and Russell and Landes (1940), though none of the fine-grained siliceous type described by Williams and Phemister was observed. Those occurring within the Cypress Lake map-area consist of medium-grained, pale grey to buff and limonitic sandstones. In width they seldom exceed a foot, and some have been traced for 100 feet. All are steeply dipping.

Much has been written about these dykes. In southeastern Alberta Williams and Dyer (1930, p. 80) found the sandstone dykes crossing a lignite bed at the top of the Oldman formation and extending upwards into overlying Bearpaw shale; they found them, also, 100 to 200 feet above the base of the Bearpaw, and also in the upper 200 feet of this formation, where a number of small dykes converge upwards into a large mass of sandstone. Williams and Phemister, on the basis of lithological similarity and spacial relations of the dykes, conclude that the sandstone comprising the dykes was derived from the Oldman formation, and injected upwards into the Bearpaw shales at the end of Bearpaw time and prior to the deposition of the "Fox Hills" formation. Russell and Landes (1940, pp. 98, 99) point out that many of the dykes wedge out at their bases and do not reach the Oldman formation; that the material of the dykes is not entirely similar to the sediments of the Oldman formation; and that some of the dykes, if derived from this formation, would have had to be forced upwards some 800 feet to reach their present stratigraphic position. They submit an alternative hypothesis, namely, that the dykes are fissure fillings from above and from the side, introduced apparently by surface agencies, during late Tertiary time, when the topography was similar to that of today.

To the observations of previous investigators the present writer adds the following: at many places the sandstone dykes occur in two intersecting parallel sets, as in the NW. $\frac{1}{4}$ sec. 25, and the SE. $\frac{1}{4}$ sec. 36, tp. 5, rge. 30, W. 3rd mer. Others occur in *en échelon* arrangement, as in the NW. $\frac{1}{4}$ sec. 25, tp. 5, rge. 30. The dykes, therefore, occupy openings that have resulted from the application of stress to rocks that were sufficiently rigid to transmit that stress throughout a considerable area. From this it may be inferred that the fractures must have been developed after the shales had reached an advanced stage of induration. Alteration zones or aureoles border many of the dykes to a width, commonly, of $\frac{1}{8}$ inch, but in places for as much as $\frac{1}{2}$ inch. The alteration appears to have resulted mainly from the introduction of carbonate and limonite, and may be clearly observed along sandstone dykes in the NW. $\frac{1}{4}$ sec. 25, tp. 5, rge. 30, and along sandstone dykes that are exposed in high cut banks on the east side of Battle Creek, in the SW. $\frac{1}{4}$ sec. 16, tp. 7, rge. 29. At the latter locality there is much evidence of lateral migration of the material comprising the dykes (Figure 3, A, B, C, and D). At this locality they occur in a series of interbedded, dark grey to dark brownish grey shale and greenish grey, fine sandstone of the Bearpaw formation above the Oxarart member. The relations of the dykes to the beds of shale and sandstone are illustrated by the vertical sections shown in

Figure 3. In contrast with the greenish grey, fine sandstone interbedded with the shale, the sandstone comprising the dykes is brown and rich in limonite. Many of these dykes are only 2 inches wide, and tiny fractures extend down their middles. The dykes are poorly developed in the shale beds, and in many instances are completely cut off at their contact with them (Figure 3C). Many

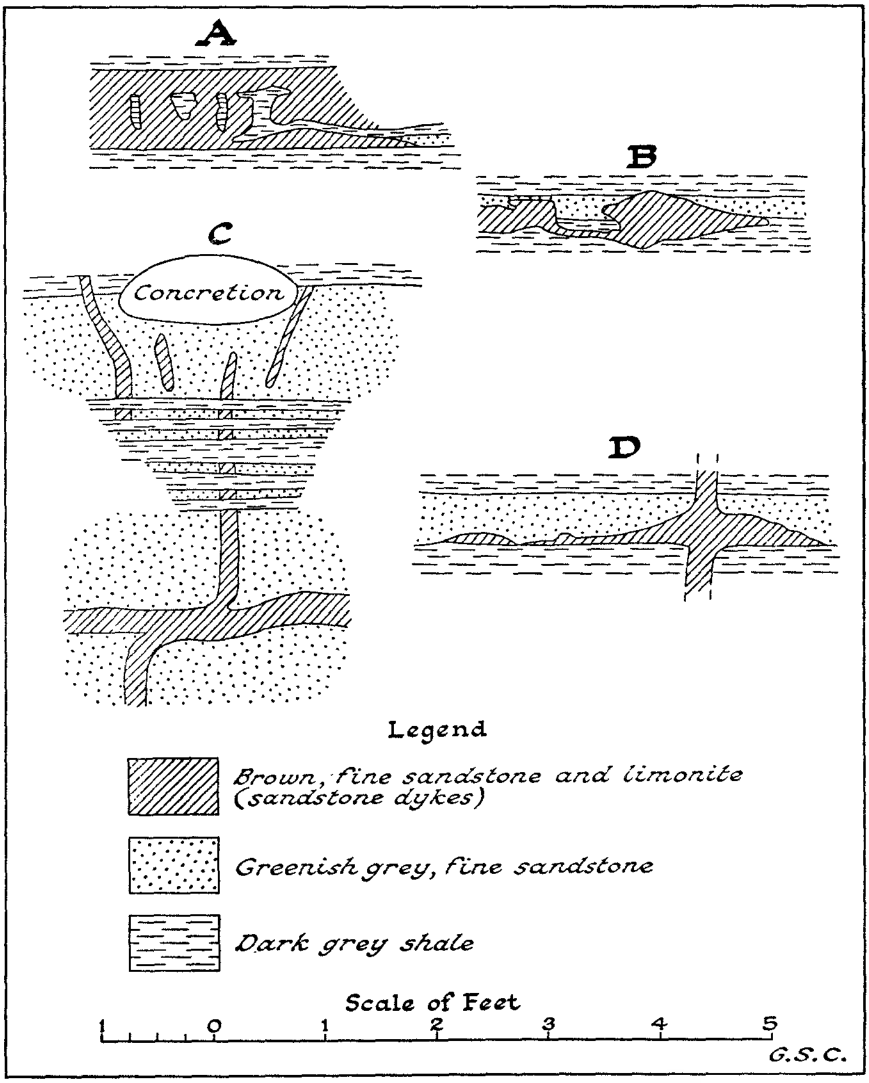


Figure 3. Vertical sections illustrating relations of sandstone dykes to interbedded shale and sandstone beds of the Bearpaw formation.

of the dykes pinch out below concretions, or are diverted laterally away from them (Figure 3C), suggesting that the development of the dykes post-dated the development of the concretions. A form of replacement is suggested in many of the exposures, and is well illustrated in those sketched (*See* Figure 3, A, B, and D). Figure 3A shows remnants of the horizontally bedded shale in the brown, limonite-rich sandstone. Figure 3B illustrates irregular penetration of the

horizontally bedded shale and greenish grey sandstone by the limonite-rich, brown sandstone of the dykes. Figure 3D illustrates the lateral penetration of greenish grey sandstone by the brown sandstone from a vertical sandstone dyke. The brown sandstone has penetrated along the contact of the greenish grey sandstone and an underlying shale bed.

Limonite is abundant in the sandstone dykes in the NW. $\frac{1}{4}$ sec. 25, tp. 5, rge. 30, W. 3rd mer. At the north end of a small gully along the west side of a large outcrop of Bearpaw shale, below the Oxarart member, a number of buff weathering dykes, several inches wide, occur *en échelon.* The horizontally bedded shale shows no change in dip at the margins of the dykes. At places, branch dykelets $\frac{1}{8}$ inch thick branch from the dykes into the dark grey, non-sandy shale. Though the dark shale is crossed irregularly by fine fractures along which iron-oxide-bearing solutions have passed and coloured the shale brown, these fractures do not cut the dykes, but end abruptly at the dyke walls. Some of the branch dykelets appear to follow these fractures. All the evidence seems to indicate that the system of minor fractures developed in the shale prior to the formation of the sandstone dykes, or simultaneously with the formation of the major fractures along which the dykes lie. In general, the sandstone dykes are most abundant in the sandy parts of the Bearpaw formation.

CHAPTER VII

STRUCTURAL GEOLOGY

GENERAL STATEMENT

The structure of the region is difficult to determine. Only three deep wells have been drilled in the map-area, and the records for one of these, Maple Creek No. 1, drilled in 1909, in sec. 15, tp. 11, rge. 26, is incomplete and of little value. The Northwest Boundary No. 1 well, drilled in 1920 by the Northwest Company, in l.s.d. 4, sec. 9, tp. 1, rge. 27, commenced in upturned beds and penetrated a thrust fault at a depth of 1,230 feet in the Lea Park formation. A few feet of Palæozoic limestone is reported to have been penetrated at the bottom of the well, but there is some reason, as previously stated, for believing that the limestone may be of Jurassic age. The Twin Province No. 1 well, 55 miles northwest of the Northwest Boundary No. 1 well, in sec. 21, tp. 11, rge. 29, was drilled in 1934 to a depth of 2,095 feet, some 500 feet below the top of the Alberta shale, and during 1942 to 1944 was deepened to 3,677 feet. The bottom of the well is thought to be in Palæozoic limestone. A fourth well, Gem Dome Oil and Gas No. 1, in l.s.d. 6, sec. 4, tp. 10, rge. 29, was commenced as a full-gauge hole, but was subsequently abandoned at a depth of only 300 feet. There is, therefore, very little data on the subsurface formations within the map-area on which to base a study of either regional or local structures. Some idea of the general structure may, however, be secured by extrapolating information from nearby areas for which more data are available. In so far as the Cypress Lake map-area lies broadly between the Sweetgrass arch of Alberta and the Williston basin of central Saskatchewan, where subsurface data is also scanty, regional trends are difficult to predict, and the projection of available data not very satisfactory. It became apparent, therefore, at the beginning of this investigation, that some surface horizon would have to be contoured. Studies of structures in the southern Plains of Alberta that had been tested by deep drilling, and for which data were available, showed clearly that surface or near surface strata, if not younger than Upper Cretaceous, do reflect the structure not only at the base of the Cretaceous but also, though slightly modified, in the Jurassic and at the surface of the Palæozoic. Generally the structures are more marked at depth than at or near the surface.

Members of the marine Bearpaw formation provided the most suitable and widespread marker horizons for structural purposes. The best of these are the Oxarart and Belanger sandstone members, 25 to 30 feet apart. The accompanying structure-contour map, No. 856A, was prepared by contouring the top of the Oxarart sandstone member. Where this member, or the Belanger member, failed to outcrop, elevations were determined on other horizons in the Bearpaw, Eastend, Whitemud, or Battle formations, the latter two of which provide excellent reference horizons. Vertical intervals were determined from such horizons to the top of the Oxarart at various points in the area, and the elevation of the Oxarart calculated therefrom. Small variations in the vertical intervals were found from one side of the area to the other, and the calculated elevation of the top of the Oxarart by this means may well be in error as much as 10 feet or more, but rarely in excess of 25 feet. However, even though errors of this magnitude may exist in the calculated elevations for the top of the Oxarart, a

structural map compiled on this data should be of value in indicating the general structural features of the area. It must be realized, however, that surface outcrops alone in this area, as well as in most areas of the Plains, do not provide sufficient data for a final, structural compilation, and that the data supplied should be supplemented by shallow-test drilling for the purposes of confirming correlations and checking elevations of key horizons in critical areas. It should be implicitly understood that structural features shown on Map No. 856A and based only on available outcrops are subject to confirmation by such test drilling. The map is prepared only for the purpose of indicating areas that in the opinion of the writer warrant further investigation.

A study was made of the water-well logs in the area in an effort to supplement surface data in those areas where outcrops are absent or sparse. It was found that many of the wells did not reach bedrock; that many penetrated fine sandstone identified as Eastend; and that others passed through a few feet of shale or "clay", commonly logged as Bearpaw, in which no horizon markers were available. A few of the latter proved of value in checking the dip of the beds in the southeast part of the area where outcrops are sufficiently close to permit a rough estimate of the stratigraphic position of the zone. For example, a water well, drilled in 1928 to a depth of 635 feet for the town of Senate, in the NE. ¼ sec. 3, tp. 4, rge. 28, penetrated to the Oldman formation. The well passed through dark shales from 250 to 590 feet, sandy material from 590 to 635 feet, and encountered a coal seam at 590 feet. In the Twin Province No. 1 well the first substantial coal seam is 76 feet below the top of the Oldman formation, and at Woodpile Coulée it is 80 feet below the contact. The contact of the Bearpaw and Oldman formations in the town of Senate water well is, therefore, assumed to lie at a drilling depth of about 512 feet.

FOLDING

The two main structural features of the area are the broad, central, easterly trending, eastward plunging anticline that underlies the central part of the Cypress Hills and that henceforth will be referred to as the Cypress Hills anticline, and the Thelma Creek syncline, which appears to be the northwestward continuation of the Coburg syncline of Montana across the southwest corner of the map-area. The Cypress Hills anticline has a width of from 15 to 20 miles, and an average eastward dip of 10 feet a mile. Its crest has a general east-west strike, and lies roughly along the south boundary of township 9.

The structural features of the area may be conveniently considered under three units: (1) those north of the Cypress Hills; (2) those south of the hills; and (3) the central hills area.

FOLDS NORTH OF THE CYPRESS HILLS

Along the northern flanks of the Cypress Hills the beds dip north at 50 to 60 feet a mile. North of the hills this dip decreases gradually, and the strike swings to the northwest, a trend quite apparent at the west side of the map-area. The north component of dip in the north part of townships 10 and 11 averages 13 feet a mile. That the strata north of the Cypress Hills have a regional north component of dip that flattens towards the north and steepens southwards has been established by data from outside the map-area and by every worker who has studied the region. The regional northward component of dip has been estimated at 10 feet a mile between Neidpath and Beechy, Saskatchewan (F. J. Fraser *et al.*, 1935, p. 60). On Ross Creek, south of Irvine, Alberta, Williams and Dyer record dips of 10 to 15 feet a mile; south along the creek the dip is progressively steeper, whereas north of Irvine the rocks are nearly flat (Williams

and Dyer, 1930, pp. 82 and 85). J. S. Stewart (1941, p. 2) confirms these observations. Between township 16 and Red Deer River, along South Saskatchewan River, he records a northward dip of about 5 feet a mile.

A measure of the eastward component of dip north of the hills is indicated by the drop of 80 feet in 18 miles of the base of the Bearpaw formation from its exposures south of Irvine to the Twin Province No. 1 well. This would indicate an average eastward component of dip between these two points of about 4·5 feet a mile.

As outcrops are limited north of the Cypress Hills, little structural detail can be provided. Map No. 856A indicates that, in general, the beds strike only slightly north of east, except west of range 28 where the strike swings to the northwest.

FOLDS SOUTH OF THE CYPRESS HILLS

South of the Cypress Hills the beds dip southeast and south at a low rate. This is shown by structure contours (Map No. 856A) on the top of the Oxarart. The general southward drop in elevation has been checked by observing the elevation of the Bearpaw-Oldman contact at Woodpile Creek, and those of the Whitemud, Eastend, and Belanger beds exposed on Boundary Plateau.

Six bentonite layers are present in nearly flat Bearpaw shales exposed along Woodpile Coulée for a mile southeast of the Northwest Boundary No. 1 well. An excellent section of the strata from the lower Bearpaw to the Lea Park formation is exposed along this coulée north of the well. These strata have been thrust up and northward along an east-west fault less than a mile north of the well, and have an average dip of about 45 degrees south. The six bentonite beds are exposed in the upturned strata south of the fault. The distance from the bentonite layers to the contact with the Oldman beds, at the top of the first brown organic bed, was carefully determined. From this, the elevation of the base of the Bearpaw formation, half a mile south of the Boundary well, was determined as between 2,635 and 2,650 feet. Furthermore, as strata south of this well are on the upthrown side of the east-west thrust fault, the gliding plane of which is in the lower part of the Lea Park formation, the elevation of the base of the Bearpaw formation north of the thrust fault must be even lower than 2,635-50 feet. Again, at the town of Senate water well, the elevation of the Bearpaw-Oldman contact is 2,665 feet.

These elevations may be compared with one of 2,512 feet for the same horizon in the Twin Province No. 1 well. At the Gem Dome Oil and Gas well the contact is estimated to lie 110 feet below the bottom of the well, or at an elevation of 2,638 feet. Though these figures are lower than those given above, it should be noted that the north dip for the strata between these wells and the central Cypress Hills would indicate an elevation for this horizon in excess of 2,850 feet in the central part of the hills. A reverse in the north-south dip component must be inferred for the area south of the hills.

The top of the Whitemud formation of Boundary Plateau, in sec. 15, tp. 1, rge. 23, is 213 feet lower than the same horizon on the north side of Frenchman River Valley, in sec. 26, tp. 6, rge. 23. The base of the Whitemud, at the west end of Old Man On His Back Plateau, is at an elevation of 3,450 feet. As the normal thickness for the formation in this part of the area is 55 feet, the elevation of its top would be 3,505 feet as compared with 3,212 feet at Boundary Plateau. The difference in elevation between these two points represents an average drop in elevation of 16·5 feet a mile southeast.

The Belanger member outcrops at an elevation of 3,237 feet at the west end of Old Man On His Back Plateau, in sec. 15, tp. 3, rge. 25, as compared with

2,944 feet in Coteau or Sand Coulée in sec. 6, tp. 2, rge. 23. The difference represents an average drop in elevation of 21·7 feet a mile, from northwest to southeast, between these two exposures.

Bedrock exposures are slightly more abundant and more widely distributed south of the Cypress Hills than to the north. Consequently, more detail structure is apparent. Four structural features, exclusive of faulting, are worthy of note. These are the Old Man On His Back nose, the Robsart syncline, the Govenlock nose, and the Thelma Creek syncline.

Whitemud and Eastend beds and the Belanger member of the Bearpaw formation provide structural horizons for mapping along the southwest slopes of Old Man On His Back Plateau. The strikes of the beds are here northwest in contrast with the regional northeast strikes. The dip is southwest. The Belanger member outcrops at an elevation of 3,142 feet, in sec. 19, tp. 3, rge. 25, as compared with an elevation of 3,237 feet at the west end of Old Man On His Back Plateau, in sec. 15, tp. 3, rge. 24. The average drop between these two points, from east to west, is 35 feet a mile. As this reverse in dip is contrary to the regional dip, though not in the critical direction, a structural nose is suggested. As there are no exposures for some 15 miles farther north, little is known of the dimensions or shape of this nose. A few water wells, 10 to 14 miles northeast, provide some control in this direction. However, the dominant northeast strike along the south slopes of the Cypress Hills, as shown on the structure-contour map, necessitates postulating an east-trending syncline through Robsart in order to swing the contour lines eastward around the east side of Old Man On His Back Plateau. This syncline may be referred to as the Robsart syncline. There is no indication of critical closure on the Old Man On His Back structure.

The Govenlock nose underlies the south half of tp. 3, rge. 28, some 6 miles southeast of Govenlock. The axis of the nose appears to strike northwest through Govenlock. The presence of this nose is suggested by the Bearpaw beds exposed in secs. 11 and 12, tp. 3, rge. 28, on the south side of the coulée. These include a bentonite bed and a layer of ivory weathering to dark purplish brown concretions carrying abundant *Baculites* sp. and encrusted or underlain by a layer of aragonitic cone-in-cone material. This places the beds in the aragonite zone of the Bearpaw, which occurs 290 to 430 feet above the base of the Bearpaw. A correlation of these beds with those along the north end of Woodpile Creek indicates that they are approximately 360 feet above the base of the formation. Foraminiferal evidence likewise indicates these beds are from a very low section of the Bearpaw. If Wickenden's limits are correct, and these beds are restricted to the lower 100 to 150 feet of the Bearpaw, then the Govenlock nose is even more pronounced than is shown on the structure-contour map. Little is known of the size or shape of this feature, or whether any critical closure exists.

The Coburg syncline is the name given in Montana to the structure that separates the Bowdoin Dome from Bearpaw Mountains. It is a well-defined syncline of considerable relief where it passes between these features. It strikes generally northwest-southeast, but its northwestward extension, near the International Boundary, cannot be traced with any degree of certainty. Evidence from the Cypress Lake area indicates the axis of a syncline striking northwest from about the south side of township 3, on the Saskatchewan-Alberta boundary, to the west side of range 28, at the International Boundary. The axis of this syncline almost coincides with the course of Thelma Creek and may be referred to as the Thelma Creek syncline. It is suggested that this syncline may be the northwestward continuation of the Coburg syncline, and that it continues northwestward into Alberta between the west end of the Cypress and Sweetgrass Hills. The Bearpaw beds exposed in sec. 9, tp. 3, rge. 30, were placed, on

the basis of lithology, at 325 to 375 feet above the base of the Bearpaw formation. Subsequent studies of the foraminifera in the shales exposed here shows them to be similar to the fauna found in the lower beds of the Bearpaw formation in the Manyberries area and to the fauna in the beds exposed in sec. 12, tp. 3, rge. 28. This data would indicate the base of the Bearpaw formation here to be at an elevation of about 2,690 feet. It is of interest to note that Williams and Dyer (1930, p. 85) mapped a structural depression that extends from the vicinity of Altawan northwesterly to the northwest corner of tp. 5, rge. 3, W. 4th mer., in Alberta. This would appear to be an extension of the same syncline crossing the southwest corner of the Cypress Lake area.

FOLDS IN THE CENTRAL HILLS AREA

Though the general axis of the Cypress Hills anticline, underlying the central Cypress Hills, strikes slightly north of east across the map-area, the secondary structural features show an alinement in an east-northeast direction. The dips on the north slopes of the hills approach 50 feet a mile, at places, and are much steeper than those on the south and southeast slopes where dips average 15 to 25 feet a mile, and only exceptionally reach 50 feet.

The average structural relief on the major Cypress Hills fold, measured in a north-south section, as along the west side of range 26, is about 450 feet from the crest of the anticline south to the International Boundary, in approximately 45 miles, and is estimated at 450 to 500 feet from the crest of the anticline to the northern boundary of the map-area. This latter estimate is based upon an assumed average northward dip component of 10 feet a mile for the northern 18 miles where exposures are lacking.

The average eastward plunge of the axis of the fold is 13 feet a mile. The axis continues to rise at about this rate into the western end of the Cypress Hills, as indicated by the elevations of the Whitemud, Belanger, and Oxarart beds along the east side of Medicine Lodge Coulée, in Alberta. In the section measured, on the north side of the ravine, in the SW. ¼ sec. 7, tp. 8, rge. 3, W. 4th mer., in Alberta, the top of the Oxarart member is at an elevation of 3,865 feet. This is 260 feet higher than the highest calculated elevation for the Oxarart member on the west side of the Cypress Lake map-area, and the rate of rise is 12·3 feet a mile between these points.

The important secondary structural features are the Park structural nose, the Adams Creek structural nose, and the Battle Creek syncline.

The Park structural nose underlies the area occupied by the Cypress Hills Provincial Park, in the SW. ¼ tp. 9, rge. 26, and NW. ¼ tp. 8, rge. 26. The nose appears to have a width of some 4 miles and to trend east-northeast. Structural relief on the nose is approximately 75 to 125 feet. Southwest of the park lies the broad topographic feature known as "The Gap". Bedrock is here completely obscured by glacial drift, so that it is not possible to determine if any structural closure is present in this direction. However, a marked flattening of dip occurs between the exposures in the park and the next exposures on Adams Creek, some 15 miles southwest. This suggests the possibility that "The Gap" may coincide with a structural low or saddle.

The Adams Creek structure underlies the SW. ¼ tp. 7, rge. 28. Structural relief is much less here, amounting to 50 to 60 feet. The nose is 4 to 5 miles across, and has a rather ill-defined northwesterly trend. Evidence for structural closure in this direction is lacking.

The Battle Creek syncline flanks the Adams Creek nose on the west and southwest. It is a rather sharp, narrow syncline some 4 miles wide, trending northerly and plunging southward at about 13 or 14 feet a mile. Its maximum

depth does not exceed 100 feet. A similar, but less well defined, shallow syncline appears to trend northeast across tp. 8, rge. 28, and plunges northeastward. It may be that this is a northeastward expression of the Battle Creek syncline, and that a saddle crosses the northwestward continuation of the Adams Creek structural nose.

FAULTING

Faulting, other than near the surface, is known to occur at two places within the map-area, namely, at Woodpile Creek, north of the Northwest Boundary No. 1 well (*See* Figure 4), and along Bear Creek on the west side of tp. 10, rge. 23. The strata in the folded areas are thoroughly folded and faulted. Minor drag-folding and, at places, fracture cleavage have developed. The evidence most strongly favouring deformation under pressure, rather than near surface faulting, is the condition of the bentonite beds associated with the Bearpaw and Oldman-Foremost strata involved in the deformation. Elsewhere in the area the bentonite beds are soft and plastic. In the deformed beds of the two areas referred to, the bentonite beds are generally hard, indurated, and broken by numerous fractures with slickensided surfaces.

The deformed strata at Woodpile Creek (*See* Figure 4) are discussed by Williams and Dyer (1930, p. 85). They underlie an area little more than ½ mile broad and at least 3½ miles long. Upturned beds are exposed both on Woodpile Creek and on a small coulée crossing the south boundary of section 11, 3½ miles east. The strata involved in the faulting and folding include the lower 200 to 300 feet of the Bearpaw beds, the Oldman and Foremost beds, and the upper part of the Lea Park. The beds all have a general easterly trend, with local variations amounting to 30 degrees. Dips are all to the south and range from 33 degrees, at the south side of the upturned strata, to 45 and 50 degrees half a mile north. At the surface the fault plane lies to the north and stratigraphically below exposures believed to be Lea Park. Slickensided shale and lignite, the latter, regarded as fault drag, at a depth of 1,230 to 1,240 feet in Northwest Boundary No. 1 well, is believed to represent the fault plane. This is 240 to 250 feet below the top of the Lea Park formation. On the west side of Woodpile Creek, 1,600 feet north of the most northerly exposure of steeply dipping strata, are flat-lying Bearpaw beds. Similarly, 400 feet south of the most southerly exposures of upturned beds, are flat-lying Bearpaw beds. The approximate elevations of the Bearpaw-Oldman contact north and south of the deformed belt were arrived at by correlation with other sections of the area and with theup-turned beds. South of the fault the contact is approximately 150 feet higher than the estimated position of the contact north of the fault. It would appear, therefore, that the total vertical displacement on the fault is small. The fault appears to be a simple thrust affecting only the beds above the Lea Park formation. The faulting is due to a shortening of the strata, associated, most probably, with the arching of the area of the Cypress Hills and with contemporaneous uplift and igneous intrusion in the Bearpaw Mountains of Montana, only 60 to 70 miles apart, in Eocene or early Oligocene time. The fault lies about midway between these uplifted areas. The flat-lying strata between them would be compressed differentially, the beds at depth being subjected to a small lateral compressive stress relative to the vertical stress, whereas the upper beds would be subjected to a much greater lateral compressive stress. This could be relieved either by buckling of the upper beds upon gliding planes in the lower beds, or by thrust faulting along shallow gliding planes that are almost bedding plane faults, or by a combination of both. Faults of this nature are prolific in an annular area surrounding and extending outwards from Bearpaw Mountains. These have been described thoroughly and their origin discussed by Frank Reeves (1925), who finds that only the late Upper Cretaceous beds are involved

in this type of deformation; the faults appear to die out along bedding planes and do not penetrate to depth.

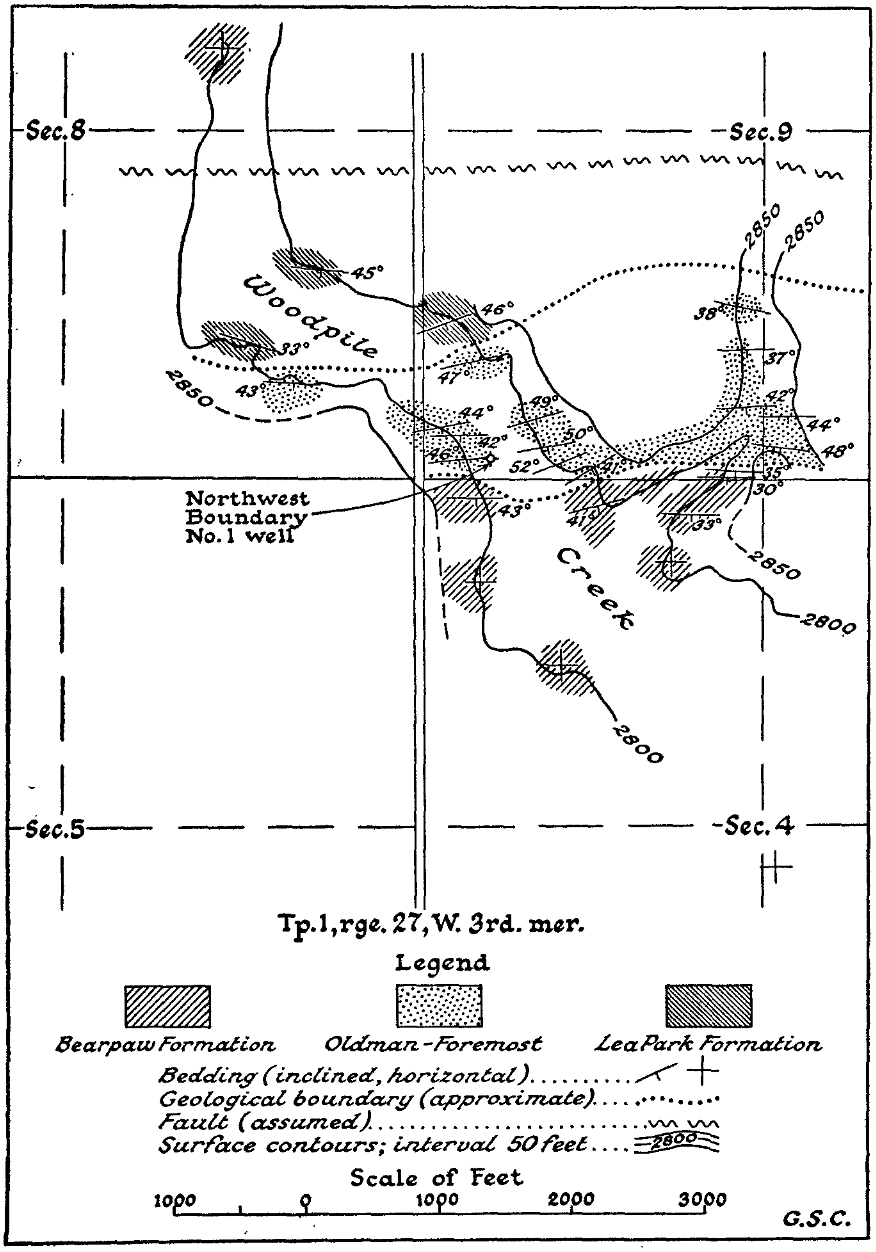


Figure 4. Faulted beds along Woodpile Creek in SW. ¼ tp. 1, rge. 27, W. 3rd mer.

The strata involved in the deformation along Bear Creek include a large section of the Bearpaw beds, apparently including the Oxarart and Belanger members, and possibly including some Eastend beds. Outcrops of the steeply

dipping beds extend along Bear Creek from sec. 31, tp. 9, rge. 23, to sec. 29, tp. 10, rge. 23, a distance of nearly 6 miles, and across a maximum width of about a mile. Dips range up to 65 degrees and, unlike the upturned strata in Woodpile Coulée, the strikes vary greatly in direction. Most of the exposures are isolated outcrops from which little can be learned of the character of the deformation. However, more extensive exposures occur in the SW. ¼ sec. 7, tp. 10, rge. 23. The beds here strike generally north 10 to 20 degrees east, and dip as much as 68 degrees east. Minor faulting strikes northeast to north. Minor drag-folding of carbonaceous shale and lignitic beds indicates a relative displacement of the western beds southwards. This and other minor folds plunge southwards at angles of less than 45 degrees. The drag-folding, therefore, would indicate that the beds to the east have been thrust upwards relative to those west of the deformed belt. As the beds in general dip east, this would imply thrust faulting. Faults no doubt lie west of these exposures, but are concealed by drift. If the minor faults and folds referred to above reflect the major displacement, then it may be that the beds have been thrust westwards and upwards. However, the irregular character of the strikes and dips indicates that the structure is much more irregular than that at Woodpile Coulée. Outcrops are insufficient to permit any definite conclusions regarding the character or origin of the deformation.

DATE OF FOLDING AND FAULTING

It is not possible to date exactly the age of the latest period of folding and faulting discussed in the foregoing pages. However, there is evidence[1] to indicate that folding occurred in pre-Oligocene, and probably late Eocene, time. The faulting, at least that along Woodpile Creek, that occurred in conjunction with the uplift and folding of the Bearpaw Mountains and Cypress Hills, would likewise have occurred in pre-Oligocene and probably late Eocene time.

[1] *See* Chapter VIII.

CHAPTER VIII

ORIGIN OF THE CYPRESS HILLS

THE PROBLEM

The problem of the origin of the Cypress Hills has attracted considerable discussion since the first comprehensive study by McConnell, in 1885. Direct evidence is incomplete, and though the present structural mapping indicates that the hills are anticlinal, it is uncertain how long, geologically, the area underlain by the hills has been a positive element.

McConnell (1885) first drew attention to the eastward-sloping, plateau-like surface of the hills established upon indurated conglomerate and sandstone now known as the Cypress Hills formation. Though first regarded as Miocene (McConnell, 1885, pp. 68-70), the age of this formation has since been determined chiefly as Oligocene, though some of the lowest beds may be as old as Upper Eocene. McConnell and all subsequent workers agree that the materials comprising this formation were derived from the Rocky Mountains, 200 miles to the west, and that they represent alluvial deposits formed by vigorous streams heading in these mountains. McConnell regarded the rocks as having been deposited in basins and recognized that they had at one time been widely distributed throughout a large part of the western plains. Lithologically similar rocks occur in the Hand Hills of central Alberta, just east of Drumheller, and on the Swan River Plateau south of Lesser Slave Lake, Alberta.

W. C. Alden (1924 and 1932) made an extensive study of the Great Plains of northwestern United States. He found Oligocene deposits, similar in character to those in the Cypress Hills, distributed over a wide area in Montana, the Dakotas, and Wyoming. The surfaces of these he correlated into a plain that he named the Cypress Plain. He conceived these deposits as having "spread over a broad, gently sloping, nearly flat plain composed of coalescing fans heading at those points where the streams debouched from the mountain gorges". The wide distribution of later gravels obviously derived from rocks similar to those comprising the Cypress Hills formation support this view.

McConnell, discussing the origin of the Cypress Hills states:

"The area now covered by the Cypress Hills has been changed from a depression in . . . . . (Oligocene) times into the highest plateau on the plains, which is its present position, entirely by the arrest of denudation over its surface by the hard conglomerate beds which cover it, whilst the surrounding country, destitute of such protection, has been gradually lowered and so affords an index of the amount of material removed from the neighbouring plains in the age intervening between the deposition of the . . . . . (Oligocene) and the glacial period."

This concept of McConnell's has been quoted and concurred with by subsequent workers in the area, including Williams (Williams and Dyer, 1930, p. 93) and Alden (1932, pp. 4-10). However, geological maps of the Cypress Hills show a surprising degree of retrenchment into the Cypress Hills formation by very small tributary streams. The conspicuous retrenchment, by such small creeks as Bone Creek, at the east end of the Cypress Hills where the formation is thick, raises doubt that this formation is so resistant to erosion as had been

supposed. Evidence has been presented to show that tributary streams such as North Frenchman River, that are in obsequent arrangement to the main drainage system, developed during Pleistocene time when glaciers and glacial deposits temporarily blocked the normal drainage channels. If so, erosion along such streams must have occurred during a brief period geologically, and this appears to provide a measure of the ability of small streams to erode the Cypress Hills formation in relatively short time.

Accepting Alden's concept of an extensive Cypress Plain underlain by Oligocene conglomerates, the question arises as to why the eroding agents, which removed the greater part of the rocks underlying this plain, did not complete the erosion of the relatively small area of the Cypress Hills. The inference appears warranted that other factors in addition to resistance to erosion were operative.

In 1930 Wickenden found an Eocene fauna in a hard, conglomeratic sandstone southeast of Swift Current, Saskatchewan. This discovery was the subject of subsequent investigation by Russell and Wickenden (1933, p. 53), the results of which confirmed the presence of a late Eocene fauna. The Swift Current conglomeratic sandstone lies some 950 feet lower than the younger, Oligocene, Cypress Hills formation. Russell and Wickenden pointed out that this was not due to deformation of the strata, for the high beds rest on Paleocene, Ravenscrag sediments, and the lower on the Cretaceous, Bearpaw shale. They conclude, therefore, that:

" . . . . . southwestern Saskatchewan was subjected to erosion (coincident with the Laramide revolution and uplift of the Rocky Mountains) in the early or Middle Eocene and that as much as 950 feet of sediments were removed in places. The site of the Cypress Hills, however, suffered much less denudation, and by Middle Eocene time stood as a relatively high area, sloping away to the south, east, and northeast in somewhat the same manner as today."

Aggradation in this area commenced in late Eocene time, according to Russell and Wickenden, when erosion of the uplifted Rocky Mountains 250 miles to the west reached an advanced stage, and continued into Oligocene time. Their conception is that sheets of gravel and sand were deposited first around the flanks of the Eocene Cypress Hills and later over this upland in Oligocene time. As the Laramide revolution died out, the forces of erosion overcame the forces of aggradation and a second erosion cycle, commencing in late Oligocene or Miocene time, eroded the plains of southwestern Saskatchewan to their present level and once more isolated the Cypress Hills as an upland. In conclusion, they point out that this view is in contrast with previously held ideas that the Cypress Hills area was a basin in Oligocene time.

Thus we have the conception that the Cypress Hills existed as an upland in the plains at least twice in Tertiary time. Though the hills are now topped by beds of conglomerate that may or may not have resisted erosion, such was not the situation in pre-Oligocene time. Underlying the capping Cypress Hills formation in the Cypress Hills are the very soft Ravenscrag shales, silts, and fine sands. These, it would seem, could offer little resistance to eroding agents. The problem arises, therefore, as to what caused the development of the Cypress Hills of Eocene time.

The present investigation provides new structural data on the area. These data indicate that some revision is necessary of former views concerning the origin of the hills. However, evidence concerning the physiographic and tectonic history of the hills is scant and it seems advisable to consider this area in its relation to the much larger area of the southwestern Plains. The general physiographic and tectonic history of this province during this time will, therefore, be reviewed.

THE SOUTHWESTERN PLAINS

The Plains of southwestern Canada and northwestern United States have undergone regional differential uplifts periodically throughout Tertiary and early Pleistocene time. Gravel terraces of three different ages and at three successively lower elevations have been recognized in the Plains subsequent to the deposition of the Cypress Hills formation (W. C. Alden, 1932, pp. 13-64). Contained fossils serve to fix the age of the gravels and, thereby, the time of regional uplift and renewed erosion. The uplifts have, apparently, coincided and are correlated with uplifts of the Rocky Mountain region. A final and notable period of uplift, which permitted partial erosion of the last of these terraces, occurred at the close of the Tertiary period and the beginning of Pleistocene time (Alden, 1924, p. 409).

The amount of uplift of the Cypress Hills plain subsequent to its development has been computed by various authors. Alden (1924, p. 396) estimates that, in the south, the plain has been uplifted altogether as much as 4,000 to 5,000 feet. Lawson (1925, p. 157) calculates that on the basis of isostasy the Cypress plain west of the Cypress Hills was uplifted at least 1,680 feet. The actual amount of the total uplift is not important, however, other than that the best evidence indicates it is to be measured in terms of thousands of feet. The important consideration is that these plains have been uplifted repeatedly and concurrently with the elevation of the Rocky Mountains in Tertiary time.

The regional uplifts of the southwestern Plains were far from uniform, and were complicated further by numerous local uplifts, many of which were accompanied by intrusion of igneous material.

East of the Rocky Mountain front, in the southwestern Plains, from Wyoming through Montana and the Dakotas to the International Boundary, are fourteen outlying mountain groups (*See* Figure 5). These are areas of local uplift and igneous intrusion.

The Big Horn (*See* Figure 5) and Pryor Mountains (Thom, 1935, p. 71), the Big Snowy Mountains (Reeves, 1931, p. 135), the Castle Mountains, the Crazy Mountains (Wolf, 1935, pp. 193-5, and G. G. Simpson, 1937, p. 28), the Judith Mountains, the Little Belt Mountains, the Little Rocky Mountains, and the North and South Moccasin Mountains (Blixt, 1933, pp. 5 and 19) are all uplifted and faulted anticlines or domes of sedimentary rocks with, in most cases, igneous intrusions. The deformations have involved Fort Union (Eocene) sediments but are older than the Oligocene White River sediments.

Highwood Mountains (*See* Figure 5) were formed during a long period of Tertiary vulcanism. Lava flows of an early stage were eroded, exposing the volcanic vents. Later andesites flowed over the truncated vents of the former volcanoes.

Black Hills (*See* Figure 5) consist of a broad arch of sedimentary rocks, eroded to expose a core of Precambrian rocks and Tertiary intrusions. The Black Hills dome was uplifted in pre-Oligocene time by a movement that may have begun at least as early as the close of the Cretaceous period, and possibly earlier. During this time some 7,000 feet of sediments were eroded from the main part of the hills. The dome was truncated and most of the larger valleys excavated before the deposition of the White River (Oligocene) sediments (Darton and Paige, 1925, pp. 15 and 25). The White River group consists of three or more clearly defined divisions, of which the two lower ones are the Chadron and the Brûlé Clay formations. The Cypress Hills formation of Saskatchewan and Alberta has been correlated definitely, by vertebrate fossils, to early Chadron, that is, to the lower part of the White River group of the Black Hills

region, or lower Oligocene (Russell and Landes, 1940, p. 97). Early Tertiary igneous bodies intruded the sediments prior to the deposition of the lower Oligocene conglomerates, for these contain pebbles of the intrusive rocks. The presence of large quantities of volcanic ash in the sediments of the White River group indicates that vulcanism continued into that time. A differential uplift occurred in mid-Oligocene time; it amounted to 2,000 to 3,000 feet in the hills proper, 250 feet in the foothills, and 20 to 30 feet in the badlands (Fillman, 1929).

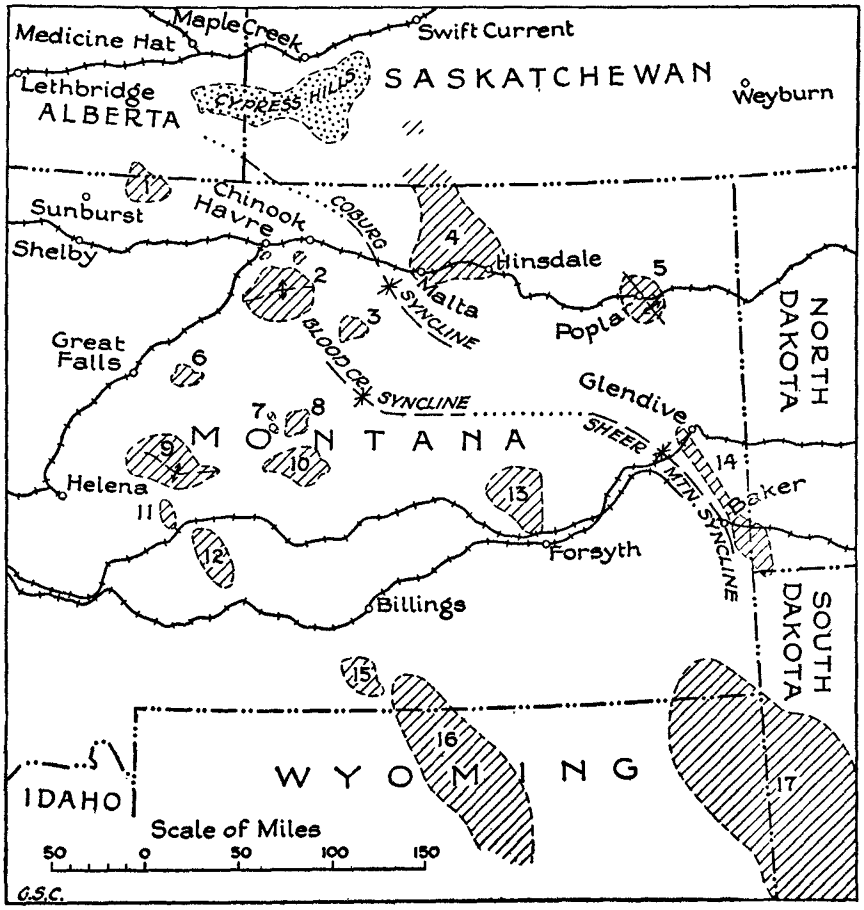


Figure 5. A part of the southwestern Plains on either side of the International Boundary, showing distribution of areas uplifted locally in Tertiary time, and corresponding position of the Cypress Hills: (1) Sweetgrass Hills; (2) Bearpaw Mountains; (3) Little Rocky Mountains; (4) Bowdoin Dome; (5) Poplar Dome; (6) Highwood Mountains; (7) Moccasin Mountains; (8) Judith Mountains; (9) Little Belt Mountains; (10) Big Snowy Mountains; (11) Castle Mountains; (12) Crazy Mountains; (13) Porcupine Dome; (14) Cedar Creek Anticline; (15) Pryor Mountains; (16) Big Horn Mountains; (17) Black Hills.

Sweetgrass Hills, 40 to 50 miles southwest of the Cypress Hills (*See* Figure 5), consist of three laccolithic buttes of early Tertiary age about which the sediments have been uplifted. The exact age of the intrusions is not known. Russell (Russell and Landes, 1940, p. 100) points out, however, that the Sweetgrass Hills uplift and intrusion occurred on the flank of the earlier formed Sweetgrass arch. This arch originated in Palæozoic time, and has been uplifted intermittently since then (Michener, 1934, pp. 59-61) in conjunction with the

development of the Rocky Mountains. Russell states that the arch involves Paleocene strata in its warping. Therefore, the intrusions are somewhat younger, that is, post-Paleocene.

The Bearpaw Mountains (Reeves, 1925, p. 187), 75 miles south of the Cypress Hills, consist of laccoliths intruded into domed sedimentary rocks that form an east-west trending anticline. The sedimentary rocks were truncated as they were elevated; the igneous material eventually broke through to the surface and volcanic rocks were extruded upon the truncated beds. Among the sediments covered by the volcanic rocks are quartzite boulder-bearing conglomerates of probable Oligocene age. Surrounding the Bearpaw Mountains are great numbers of faults and folds (Reeves, 1924, pp. 300 and 304). These have been shown to be genetically related to the mountain building forces. Some of the faults have affected Fort Union (Eocene) beds (Bowen, 1914); that is, some of the deformation associated with the development of the mountains was at least as late as late Eocene.

There are, in addition to the isolated Tertiary mountains already described, four prominent areas of Tertiary uplift in the Plains of eastern Montana that have little physiographic expression. These are the Cedar Creek anticline, the Bowdoin dome, the Porcupine dome, and the smaller Poplar dome (*See* Figure 5).

The Cedar Creek (Baker-Glendive) uplift is a 100-mile long, narrow, asymmetrical anticline that trends northwest across the eastern Montana boundary and has a total closure of some 1,500 feet. The folding occurred in post-Fort Union (Eocene) time, as beds of this age have been deformed, uplifted, and eroded from the top of the structure (Calvert, 1910).

The Bowdoin dome (Perry, 1937, p. 79; Erdman, 1935, p. 260) lies in Montana some 75 miles southeast of the Cypress Hills. What is believed to be a northward extension of the dome crosses the International Boundary at about rge. 14, W. 3rd mer. The dome is 66 miles across, from east to west, and more than 65 miles from north to south. Its total closure is some 700 feet. Erdman and Perry agree that the dome resulted from deep-seated igneous activity. Erdman presents the following evidence in support of this view: (1) the general quaquaversal form and huge size of the uplift; (2) its alinement on an arc of known igneous features—the Little Rocky Mountains, the Bearpaw Mountains, and the Sweetgrass Hills; (3) a positive gravity anomaly in the vicinity of Hinsdale; (4) hot waters in the dome at a depth of 3,200 feet; (5) a geothermal gradient about 50 per cent greater than at Kevin-Sunburst dome; and (6) the presence of basaltic igneous rock at the surface, well down on the southeast flank of the dome, about 16 miles south of Nashua. The basalt cuts late Cretaceous sediments; the time of intrusion, therefore, may be early Tertiary and, if Erdman is correct in his explanation of the origin of the structure, the dome itself may be of this age. Furthermore, it has been pointed out that the Fort Union (Eocene) sediments have been eroded from the Bowdoin dome; presumably the Fort Union was involved in this uplift (Clapp, Bevan, Lambert, 1921, p. 27).

Porcupine dome (Bowen, 1916, p. 66) south of Bowdoin dome is 33 miles across at its widest point. One vertical, 9-foot dyke of igneous rock intrudes the structure on the east side. Sections across the dome show the Fort Union (Eocene) sediments slightly upturned on the east side of the structure. Sediments of this age were apparently eroded from the dome (Perry, 1935).

Poplar dome lies some 50 miles east of Bowdoin dome. Fort Union beds have been uplifted and are eroded from it.

It seems, therefore, that in addition to regional uplifts, the southwestern Plains, in Tertiary time, were subjected to local uplifting accompanied by igneous intrusion. Sufficient data are not available to determine the time of all

these uplifts and intrusions, but it appears there have been two distinct periods of uplift and vulcanism separated by a period of erosion. The first, which may have commenced in late Cretaceous time, was most widespread in the latter part of Eocene time (post-Fort Union). This would coincide in part at least to the Laramide revolution. Erosion then truncated folds, and exposed intrusion and volcanic necks. A second period of local uplift and vulcanism appears to have occurred in middle or late Oligocene time, after the deposition of the Cypress Hills formation and early White River beds.

SUMMARY AND CONCLUSIONS

In early Oligocene time the Cypress Hills area was a plain of piedmont aggradation far above sea-level, and not a basin of sedimentation. At that time, consequent upon the uplift of the Rocky Mountains, the forces of aggradation temporarily overcame the forces of erosion in the western Plains.

The explanation advanced to account for the origin of the Cypress Hills purely through arrest of denudation by a hard covering of conglomerate may not take into account all the factors. Present available evidence indicates that the Cypress Hills existed as hills, not only in post-Oligocene time but also during Eocene time prior to the deposition of the Cypress Hills formation, when its covering consisted only of soft shales, silts, and sands of Paleocene age (Ravenscrag).

The evidence presented in the foregoing discussion shows that throughout the Tertiary period the southwestern Plains at many points underwent, in addition to repeated regional uplift, local uplift accompanied and followed in many places by igneous intrusion and vulcanism. One widespread, and probably the chief, period of uplift and igneous intrusion originated in Cretaceous time and ended in late Eocene or very early Oligocene time; a second period occurred apparently in late or post-Oligocene time.

The writer's conclusion is that the Cypress Hills area, which is indicated by the data presented in this report to be underlain by an eastward plunging anticline, was folded, like many other isolated mountain areas in the southwestern Plains, in late Eocene or very early Oligocene time, and has continued as a positive element to the present; and, furthermore, that the hills have been preserved as such because they are anticlinal and drainage channels were diverted from them.

CHAPTER IX

ECONOMIC POSSIBILITIES

OIL AND GAS

The principal purpose of the work in the Cypress Lake map-area was to determine its possibilities for the production of oil and gas, neither of which had yet been found in appreciable quantities.

Experience from deep-well drilling in Alberta has shown that beds in the upper part of the Upper Cretaceous reflect the structure at the base of the Cretaceous, as the beds are conformable to this depth. Experience has shown also, though to a more limited degree, that the structure in the Upper Cretaceous beds reflects that at the base of the Jurassic and on the top of the Palæozoic formations, unless convergences in the beds of the former are excessive, or unless there is extreme irregularity in the Palæozoic surface.

The accompanying structure contour map, No. 856A, shows the structure in the upper beds of the Upper Cretaceous, Bearpaw formation, and, specifically, that on the top of the Oxarart member. At least four structural highs are indicated that warrant investigating by shallow drilling to define them properly. These are the Park nose, the Adams Creek nose, the Govenlock nose, and the Old Man On His Back structure.

Because they lie on the major eastward-plunging Cypress Hills anticline in the central hills, the Park nose and the Adams Creek nose appear the more interesting. If critical closure were proved to exist, a reversal in the plunge of the Cypress Hills anticline would be implied, and should offer excellent structural conditions for the accumulation of oil and gas.

The three deep wells drilled for oil and gas within the map-area, namely, the Twin Province No. 1, the Northwest Boundary No. 1, and the Maple Creek No. 1, are nowhere near the Cypress Hills anticline, and are structurally very low. They by no means represent a test of the main structural features of the area. In fact the possibilities of these features are virtually unexplored.

Comparative subsurface elevations for the three deep wells within and near the map-area are as follows:

Horizon	Twin Province No. 1 well. Elevation	Northwest Boundary No. 1 well. Elevation	Signal Butte No. 1 well. Elevation
	Feet	Feet	Feet
Elevation at surface	2,652	2,776	2,915
Top of Oxarart member (estimated)	3,252	3,130	
Top of marine Lower Cretaceous	−198	−434	−315
Top of non-marine Lower Cretaceous	−528	−754	−621
Top of basal Cretaceous sandstone	−596	−934	−831
Top of Jurassic shale	−638	−974	−845
Top of Jurassic oil-bearing sandstone	(−718? tight)	Not reached	−1,191 (oil and water)
Top of main Jurassic limestone	−838	−1,154 (?)	−1,231
Top of Palæozoic	−1,018	Not reached	−1,365

The above table indicates that the top of the basal Cretaceous sandstone is 338 feet lower at the Northwest Boundary No. 1 well than in the Twin Province No. 1 well, and 235 feet lower at the Signal Butte No. 1 well. The top of the Jurassic is 336 feet lower at the Boundary well than at the Twin Province well, and 207 feet lower at the Signal Butte well. The Palæozoic surface is 347 feet lower at the Signal Butte than at the Twin Province well.

Very little is known of the subsurface stratigraphy of the map-area. Horizons to the top of the Palæozoic have, however, been penetrated at numerous wells in southeastern Alberta, and north-central Montana, and from the information thereby provided some generalizations may be attempted regarding conditions to be expected within the Cypress Lake area to this depth. Below the Palæozoic surface the only generalizations that can be drawn are based upon broad regional studies, and hence are speculative.

The chief objectives of most wells drilled in southern Alberta and northern Montana are: the basal Cretaceous sandstone zone, which includes both Sunburst and Cutbank types of sandstone; the basal Jurassic or other Jurassic sandstones; and the weathered upper surface of the Palæozoic limestone.

Though shows of oil and a few small gas fields have been encountered in sandstones in the Alberta shale, chiefly from the "Blackleaf" member, no commercial production of oil has been obtained from these beds in southern Alberta. Some oil has been produced from this member in the Whitlash field of northern Montana on the flanks of the Sweetgrass Hills, 40 to 50 miles southwest of the Cypress Lake area.

Oil in commercial quantities has been produced from basal Cretaceous sandstones in Montana, from the "Sunburst" sandstone in the Kevin-Sunburst field, from the "Cutbank" sandstone in the Cutbank field, and in the Border-Red Coulée field just west of Coutts. At places other sands slightly higher stratigraphically are found to be productive. The Sunburst type of sandstone is composed essentially of quartz, generally in association with light-coloured, bentonitic, sandy shale, whereas the Cutbank type is a salt and pepper sandstone with abundant black and some white chert, as well as quartz that is characterized by having well-developed crystal faces. Both types are widely distributed in southern Alberta at the base of the Cretaceous succession. At Taber, Alberta, 95 miles west of the Cypress Lake area, oil has been found in commercial quantities in a Cutbank type of basal Cretaceous sandstone that, in places, grades upwards into a quartzose sandstone. At Princess, Alberta, about 80 miles northwest of the Cypress Lake area, gas and some oil were found in a Sunburst type of sandstone at the base of the Cretaceous.

The Sunburst type of sandstone appears to have a wide distribution in southern and south-central Alberta, whereas the Cutbank type seems to be restricted more to the southern and western parts of the province.

The Twin Province No. 1 well penetrated 42 feet of highly quartzose sandstone at a depth of 3,248 to 3,290 feet. The top of this sandstone is at an elevation of −596 feet. The upper 3 feet is apparently tight, but the remainder consists of poorly cemented, porous sandstone, generally fine- to medium-grained, but with some coarser grains near the base. The sandstone is saturated with water. At the Northwest Boundary No. 1 well, 20 feet of medium- to coarse-grained quartzose sandstone of the Sunburst type was penetrated at a depth of 3,710 to 3,730 feet. The top is at an elevation of −934 feet, or 338 feet lower than the top of the basal Cretaceous sandstone at the Twin Province No. 1 well. At the Signal Butte No. 1 well, in the SE. $\frac{1}{4}$, NE. $\frac{1}{4}$ sec. 19, tp. 37N, rge. 15E, in Montana, about 10 miles west-southwest of the Northwest Boundary No. 1 well, the basal Cretaceous sandstone was encountered at a depth ot 3,746

to 3,758 feet, or at an elevation of −831 feet. The upper part of the sandstone is argillaceous, calcareous, and tight. The bottom 8 feet is only slightly calcareous, and is soft. The zone is saturated with water, a feature not unexpected in view of the structurally low position of the wells relative to the major structural feature of the area, the Cypress Hills anticline. The structure-contour map (No. 856A) indicates that these beds should be encountered in the Cypress Hills at elevations several hundred feet higher than at the Twin Province No. 1 well. However, it must be emphasized that in converting structures mapped in the near-surface, Upper Cretaceous beds to those at the base of the Cretaceous, cognizance should be taken of possible convergences in this interval. These will now be considered.

The top of the marine Lower Cretaceous probably marks a fairly definite time horizon. This unit thins only slightly, from a thickness of 330 feet at the Twin Province No. 1 well to 320 feet at the Northwest Boundary No. 1 well, and to 306 feet at the Signal Butte No. 1 well. The top of the Upper Cretaceous, Oxarart member of the Bearpaw is calculated to lie at an elevation of 3,252 feet in the vicinity of the Twin Province No. 1 well, and at 3,130 feet just north of the fault at the Northwest Boundary No. 1 well on Woodpile Creek. A point north of the fault is taken in the latter case, as this will give a more correct measure of the interval to the lower horizons, which are undisturbed and lie below the fault plane in the well. The interval from the top of the Oxarart to the top of the marine Lower Cretaceous at the Twin Province No. 1 well is 3,450 feet, as compared with 3,564 feet at the Boundary well (*See* table, page 138). This represents a thickening, from north to south, of 114 feet in 65 miles, or at a rate of 1·7 feet a mile, an amount almost negligible in considering local structure. Likewise, as there is little change in thickness of the marine Lower Cretaceous, there will be little difference in the intervals from the top of the Oxarart to the top of the non-marine Lower Cretaceous. These intervals are calculated to be 3,780 and 3,884 feet, respectively, at the two wells.

The non-marine Lower Cretaceous beds show more marked thickening, from 110 feet in the Twin Province well to 220 feet in the Northwest Boundary No. 1 well. This variation may be due in part to topographic irregularities at the surface of the Jurassic beds, as well as in part ordinary thinning of continental beds in a direction away from their source. The top of the Jurassic shale in the Twin Province No. 1, Northwest Boundary No. 1, and Signal Butte No. 1 wells is respectively 200, 180 (?), and 386 feet above the main body of Jurassic limestone beds (*See* table, page 138), suggesting that there may be 200 feet or more of relief on the surface of the Jurassic beds. In contrast, the Palæozoic surface is at least 180 feet below the top of the main Jurassic limestone beds at the Twin Province No. 1 well, and 134 feet below these limestone beds at Signal Butte No. 1 well; it is 380 and 520 feet, respectively, below the base of the Cretaceous beds.

It may be concluded, therefore, that structures determined in surface beds will be reflected to the basal Cretaceous beds with negligible modification; that they may be modified to the extent of 200 feet or so in beds within the Jurassic, and about 140 feet on the Palæozoic surface. Such variations are of importance in determining the presence or absence of critical closure on local structures, but are of less consideration in the determination of the larger structural features.

Though the basal Jurassic "Ellis" sandstone of southern Alberta is an important objective in oil exploration and has yielded commercial production in the Conrad area, Alberta, it is difficult to recognize within the Cypress Lake map-area. The two wells that penetrated the Jurassic in and near the area, the Twin Province No. 1 and Signal Butte No. 1, failed to find any sandstone at the lower contact of the formation. Instead, a little argillaceous conglomerate was

encountered in the Signal Butte well section. This well, however, did find oil in 57 feet of sandstone interbedded with limestone, in places oolitic, at depths of from 4,089 to 4,146 feet (*See* well log in Appendix), commencing 329 feet below the top of the Jurassic "Ellis" shale and extending to 386 feet below. Though attempts were made to produce this oil, water from above the oil-bearing beds was not shut off successfully.

The thick, massive, dense limestones underlying the petroliferous sandstone beds are not present in the section of Jurassic beds penetrated by most wells in southern Alberta. It seems probable, therefore, that these represent a section of beds older than those generally encountered in southern Alberta, and that the petroliferous sandstones lying immediately above them in the Signal Butte No. 1 well are the stratigraphic equivalents of the petroliferous "basal Ellis" (Jurassic) sandstone penetrated by the wells of southern Alberta and found to be commercially productive at Conrad, Alberta. Similarly, in the Twin Province No. 1 well the thick section of dense limestone beds below a depth of 3,490 feet (*See* well log in Appendix) probably correlate approximately with the main body of Jurassic limestone underlying the petroliferous sandstones at Signal Butte No. 1 well. The 120 feet of sandstone and interbedded shale between depths of 3,370 and 3,490 feet at the former well would seem, therefore, to include the correlatives of the petroliferous sandstones at the latter, and of the "basal Ellis" (Jurassic) petroliferous sandstone of southern Alberta. At Twin Province No. 1, however, no porosity or saturation has been reported in these beds.

The upper weathered surface of the Palæozoic limestone failed to yield commercial oil production at either the Twin Province No. 1 or Signal Butte No. 1 wells, although the latter encountered some pin-point porosity that was oil-saturated.

It is evident, therefore, that very little is known of the distribution of porous zones down to and including the upper weathered surface of the Palæozoic within the Cypress Lake map-area. However, the limited information suggests that the basal Cretaceous sandstone zone and the calcareous sandstone zone, encountered in the Ellis formation at Signal Butte No. 1 well, offer possibilities for gas and oil production. As the former is likely to be widespread, with generally some porosity, it will be necessary to define a closed structure above the water line. In the second case, as the oil-bearing sandstones appear to be represented by tight argillaceous sandstones in the Twin Province No. 1 well, there may be a possibility that the porosity in these sandstones pinches out northwards up the south flank of the Cypress Hills anticline.

Other possibilities, for which even less information is available, are offered by horizons lower in the stratigraphic section. If representatives of the Big Snowy group underlie the area, as seems most probable, and if, as suggested by Perry and Sloss (1943, p. 1292), the northern edge of the Big Snowy basin crosses the Cypress Lake area, there are distinct possibilities for stratigraphic pinch-outs or overlaps of some of its members. Perry and Sloss (1943, p. 1304) consider the sandstones of both the Heath and the Kibbey members of the group offer excellent reservoir conditions for oil accumulation. The up-dip pinch-out of these sandstones on the south flank of the Cypress Hills should be carefully investigated.

The petroleum possibilities offered by the "Mission Canyon" limestone within the map-area would depend largely upon the presence of porous zones. These appear to have an erratic stratigraphic distribution, having been found at various depths in the "Mission Canyon" of southern Alberta, though of course the variation relative to the upper surface of the formation is in part due to topographic variations on that surface. The absence of any easily recognized

reliable stratigraphie marker within this formation renders it most difficult to determine its structure or the stratigraphic position of its porous zones.

The sandstone member at the base of the "Lodgepole" formation has carried shows of oil at a number of wells that have penetrated to this depth in southern Alberta.

Below the "Lodgepole" the most important, widespread, porous zone of southern Alberta and northern Montana lies near the top of the "Jefferson" formation of Devonian age. Porosity has been found at this horizon in almost every well that has penetrated to this depth in Alberta. Generally shows of oil and gas have been found, but only in the Princess field, Alberta, 80 miles northwest of the map-area, has commercial production of oil been obtained from this horizon. Little data is available concerning the horizons below the "Jefferson".

OTHER MINERAL RESOURCES

Other mineral resources of the Cypress Lake map-area that are of economic interest are coal, clay, and quartzite pebbles, all of which have been the subject of special investigation by earlier workers.

COAL

The coal deposits of the district have been studied and reported upon by McConnell (1885), Dowling (1914 and 1915), Williams and Dyer (1930), and Fraser *et al.* (1935). The chief coal-bearing measures are near the upper contact of the Oldman formation; in the upper part of the Oxarart member of the Bearpaw formation; in the upper beds of the Frenchman formation; and in the lower beds of the Ravenscrag.

Coal has been mined in a small way from all of these measures, chiefly for local consumption. The coal is of lignite rank, slacks on exposure, and thus does not permit much handling. The seams in the Ravenscrag are the thickest, at places measuring 13 feet. This generally includes several shale beds. The coal in the Oxarart sandstone member occurs in a lenticular seam only 2 or 3 feet at its thickest. This coal appears to be a higher quality lignite than the other coals. It has a hard, shiny lustre, can be mined in blocks, and does not slack as readily on exposure. It commands a better local market than coal from other horizons, but is difficult to find because of the lenticular habit of the beds.

Coal has been mined from steeply dipping seams in the Oldman formation on Woodpile and Coal Coulées in the SW. ¼ sec. 9, and NW. ¼ sec. 4, tp. 1, rge. 27, and in sec. 11, tp. 1, rge. 27. Several seams of lignite are exposed within the upper 200 feet of Oldman beds (*See* sections, pages 31 to 36).

The lignite in the Oxarart member of the Bearpaw formation has been mined at widespread localities throughout the area. Sporadic mining was carried on at places along the north shore of Cypress Lake; along Battle Creek, in the SW. ¼ sec. 29, and sec. 33, tp. 6, rge. 29; along Fish Creek, in secs. 23, 24, and 25, tp. 8, rge. 28; and in the NE. ¼ sec. 21, tp. 9, rge. 29.

Pits have been dug in an attempt to mine coal from the Whitemud and Eastend formations, but the lignite beds are thin and of inferior quality.

Probably the greatest amount ot mining has been concentrated on the coal seam that occurs in the Ravenscrag formation at its contact with the Frenchman. Along Frenchman River Valley this seam has been mined extensively and is known as the No. 1 seam. This seam and three additional seams higher in the Ravenscrag beds have been described by McLearn (Fraser *et al.*, 1935). The No. 1 seam is 3 to 9 feet thick. Sections across it and across those that lie above

it are given on pages 102 to 105, 113, and 114. A composite section across the four coal seams exposed along Frenchman Valley is given on pages 111 and 112, in which the individual seams are described in detail. The seams have been mined at the mouth of Concrete Creek, in the SW. ¼ tp. 7, rge. 23; along the west branch of Farewell Creek, in sec. 28, tp. 7, rge. 25; in the Cypress Hills Provincial Park, along Belanger Creek, in sec. 21, tp. 8, rge. 26; along both sides of Adams Creek Valley, in secs. 17, 18, 20, 29, 30, and 31, tp. 7, rge. 28; on the west side of Adams Lake, in NE. ¼ sec. 15, tp. 8, rge. 29; in NW. ¼ sec. 1, tp. 8, rge. 29, on the east side of Adams Creek; in SW. ¼ sec. 36, tp. 9, rge. 25; in the NW. ¼ sec. 30, tp. 9, rge. 24; and along the west side of Boundary Plateau, in NW. ¼ sec. 15, tp. 1, rge. 23. No mines were operating at the time field work for this report was being carried on, and in most places the old workings had caved and to a large extent had obscured the coal seams, so that detailed sections could not be compiled.

The principal seam mined along Adams Creek occurs at the base of the Ravenscrag formation. It is 9 to 12 feet thick. In the Cypress Hills Provincial Park the seam mined along Belanger Creek has an exposed thickness of 11 feet with the base obscured by slumping. The seam mined in NE. ¼ sec. 20, tp. 9, rge. 25, consists of 3 feet of black lignite, separated by 4 inches of shale from 1·2 feet of black, hard coal. The base is not exposed. Much of the upper bed can be mined in large, hard pieces.

CLAY

The clay resources of the district have been the subject of investigations by Ries and Keele (1912-13), Davis (1918), Worcester (1929), Hutt (1930), McLearn and McMahon (1933), and Fraser *et al.* (1935). The chief source of clay within the area is from the No. 2 and 3 zones of the Whitemud formation. Clay from this source is presently being shipped to Medicine Hat potteries, mainly from Pearson's quarry and other quarries along the valley of Frenchman River east of Ravenscrag. The geological map accompanying this report shows the distribution of outcrops of the Whitemud formation within the area. Many of these exposures, however, are of the No. 1 zone or the lower white sandstone zone of the formation; in only a few are there exposures of white clay beds that might be suitable for pottery. Sections through some of these have been detailed on previous pages.

PEBBLES

The very hard, dense, quartzite pebbles that occur in the Cypress Hills conglomerate and derived conglomerates and gravel beds have been found suitable for pebble mills. Tests of these pebbles have shown them to compare favourably with pebbles imported from Denmark (Cole, 1928; Williams and Dyer, 1930, p. 138). The market in Canada, however, is not large and railway freight costs to eastern markets makes competition with foreign products difficult.

The quartzite pebbles along with pebbles of other rocks are widely distributed as talus deposits flanking the upland surfaces of the hills. The pebbles are smoothly worn, ovoid in shape, and show generally very poor sorting.

The chief consumers of such pebbles are grinders of feldspar, clays, and other minerals that must not be contaminated by iron. In addition, some cement mills and metal mines use the pebbles in place of steel balls. The total Canadian and American consumption is not more than 10,000 tons a year.

APPENDIX

LOGS OF DEEP WELLS

Northwest Boundary No. 1 Well

Location: l.s. 4, sec. 9, tp. 1, rge. 27, W. 3rd mer.
Elevation: 2,776 feet; date, 1916.
Total depth: 3,950 feet; drilling method: standard.
Sample descriptions by R. T. D. Wickenden (1932, p. 179) and G. M. Furnival, Ottawa, 1941.

Drilling depths		Thickness
Feet		Feet
0–40	Drift	40
	Oldman and Foremost	
40–50	Coquina; fine grey sandstone, fragments lignite	10
50–70	Coquina; fine grey sandstone, some black and brown organic material	20
70–100	Sandstone, grey; little lignite; shell fragments	30
100–110	Lignite	10
110–120	Shale, brown, organic, fissile	10
120–140	Sandstone, light grey; fine dark grey shale; lignite	20
140–190	Sandstone; light grey, fine, brown siltstone	50
190–200	Sandstone, light grey, medium-grained; biotite abundant	10
200–210	Shale, dark brownish grey; lignite fragments	10
210–220	Shale, grey; lignite fragments	10
220–230	Sandstone, fine-grained, grey; little lignite	10
230–250	Lignite; little dark grey shale	20
250–300	Sandstone, light greenish grey, fine; some dark grey and brown organic shale; lignite	50
300–310	Shale, dark grey to black, carbonaceous; lignite	10
310–340	Sandstone, light grey; brown siltstone	30
340–360	Shale, brownish grey; black, carbonaceous shale	20
360–380	Sandstone, light grey, bentonitic	20
380–420	Sandstone, grey, fine; brownish grey siltstone	40
420–430	Shale, grey, with black carbonaceous matter	10
430–450	Sandstone, grey	20
450–470	Shale, brownish grey, with fragments of black carbonaceous material; little grey fine sandstone; bentonite	20
470–530	Sandstone, grey; little grey shale and lignite	60
530–540	Shale, brownish grey, with particles of black organic matter	10
540–580	Sandstone, grey to light greenish grey; brownish grey shale with particles of black organic matter; some shell fragments	40
580–600	Shale, brown and black, organic, fissile; little grey sandstone	20
600–630	Sandstone, grey, medium-grained	30
630–640	Shale, dark brownish grey to black, with black organic matter	10
640–660	Sandstone, grey; bentonite	20
660–670	Sandstone, grey; black shale; siltstone	10
670–680	Missing	10
680–690	Sandstone, grey; some brown organic shale	10
690–780	Sandstone, grey	90
780–790	Missing	10
790–890	Sandstone, grey, fine-grained	100
890–900	Shale, grey, sandy; little grey sandstone	10
900–940	Sandstone, light grey, fine-grained	40
940–950	Siltstone, calcareous; little sandstone	10
950–970	Sandstone, grey; sandy grey shale	20
970–980	Shale, dark grey, sandy	10
980–990	Sandstone, grey	10

Northwest Boundary No. 1 Well—Continued

Drilling depths		Thickness
Feet		Feet
	Lea Park (Pakowki equivalent)	
990–1,020	Shale, sandy, dark grey	30
1,020–1,030	Shale, and grey fine sandstone	10
1,030–1,050	Shale, sandy, dark grey	20
1,050–1,200	Shale, medium to dark grey, foraminifera (R.T.D. Wickenden)	150
1,200–1,210	Bentonite, pale greenish grey	10
1,210–1,230	Shale, medium to dark grey	20
1,230–1,240	Shale, black, carbonaceous, highly slickensided, with thin laminæ of lignite; dark grey sandstone (fault drag material?)	10
1,240–1,450	Shale, medium to dark grey	210
1,450–1,480	Bentonite, pale green; and shale	30
1,480–1,490	Shale, grey	10
	Lea Park (Milk River equivalent)	
1,490–1,500	Shale, grey, with abundant brown silstone; a few tiny rounded chert pebbles; *Epistomina caracolla* fauna (R.T.D. Wickenden)	10
1,500–1,530	Shale, grey; grey sandstone; *Inoceramus* prisms	30
1,530–1,550	Shale, grey; grey sandstone	20
1,550–1,570	Shale, grey; *Inoceramus* prisms	20
1,570–1,610	Shale, grey; grey sandstone; brown siltstone	40
1,610–1,750	Missing	140
1,750–1,780	Shale, grey; grey sandstone; some tiny rounded quartz pebbles; few fragments of chert and brown siltstone	30
1,780–1,800	Shale, grey; grey sandstone	20
	Alberta Formation	
1,800–2,060	Shale, dark grey with white calcareous specks (first or upper speckled shale zone); sandy in part	260
2,060–2,070	Shale, dark grey; much bentonite and volcanic ash	10
2,070–2,080	Shale, dark grey, with *Clavulina* and *Bullapora* zone (R.T.D. Wickenden)	10
2,080–2,160	Shale, dark grey; *Inoceramus* prisms	80
2,160–2,280	Shale, dark grey, with calcareous white specks; fish scales at 10 feet above base	120
2,280–2,290	Shale, dark grey; *Inoceramus* prisms	10
2,290–2,320	Shale, dark grey; bentonite	30
2,320–2,390	Shale, dark grey; chert pebbles; *Inoceramus* prisms	70
2,390–2,620	Shale, dark grey; *Inoceramus* prisms	230
2,620–2,650	Shale, dark grey; some calcareous speckled shale (second or lower speckled shale zone)	30
2,650–2,800	Shale, dark grey	150
2,800–2,810	Shale and sandstone	10
2,810–2,950	Shale, dark grey; Upper Cretaceous foraminifera (Wickenden)	140
2,950–3,080	Shale, dark grey	130
	Lower Cretaceous (?) or Alberta (?) ("Blackleaf" member)	
3,080–3,090	Sand, very fine; some small chert pebbles	10
3,090–3,110	Shale, dark grey	20
3,110–3,120	Bentonite	10
3,120–3,150	Shale, grey; some bentonite	30
3,150–3,170	Sand, fine, grey; some shale	20
3,170–3,210	Shale, dark grey, some sandstone; bentonite	40
	Lower Cretaceous: chiefly marine	
3,210–3,240	Shale, dark grey; Lower Cretaceous foraminifera (R.T.D. Wickenden)	30
3,240–3,250	Shale, dark grey; with bentonite	10
3,250–3,340	Shale, dark grey; foraminifera	90
3,340–3,350	Shale, dark grey; with bentonite	10
3,350–3,470	Shale, dark grey; last Lower Cretaceous foraminifera at base (Wickenden)	120
3,470–3,530	Shale, dark grey; slickensiding in top 30 feet	60
	Lower Cretaceous: chiefly non-marine	
3,530–3,540	Shale, dark grey and greenish grey	10
3,540–3,550	Shale, bentonitic	10
3,550–3,570	Shale, bentonitic, red with some green	20
3,570–3,580	Bentonite and volcanic ash, pale green	10
3,580–3,590	Shale, pale red and green, bentonitic	10
3,590–3,610	Shale, dark grey	20
3,610–3,640	Volcanic ash; bentonite and bentonitic shale, micaceous at places	30

Northwest Boundary No. 1 Well—Concluded

Drilling depths		Thickness
Feet	*Lower Cretaceous:* chiefly non-marine—*concluded*	Feet
3,640–3,680	Shale, red and green	40
3,680–3,710	Tuff or volcanic ash, light grey with crystals of quartz, amphibole, mica, and what appear to be kaolinized feldspars	30
3,710–3,730	Sand, dark grey; 50 to 60 per cent quartz; quartz grains angular to subangular and frosted; coal fragments	20
3,730–3,750	Shale, dark grey, sandy, bentonitic	20
	Jurassic	
3,750–3,810	Shale, medium grey to dark grey; Jurassic foraminifera (R.T.D. Wickenden) 20 feet below top	60
3,810–3,900	Shale, calcareous, light to dark grey	90
3,900–3,920	Shale, dark grey, hard, fissile, slightly calcareous	20
3,920–3,930	Shale, grey, hard, fissile, highly calcareous	10
3,930–3,950	Samples missing; reported as limestone	20

Twin Province No. 1 Well

Location: sec. 21, tp. 11, rge. 29, W. 3rd mer.
Elevation: 2,652 feet (derrick floor). 1933-1945.
Total depth: 3,970 feet (Oct. 1945); samples examined to 3,677 feet.
Drilling method: standard.
Log: 0-2,570 feet, by G. M. Furnival, Ottawa, 1941; 2,570-3,677 feet, by R. T. D. Wickenden, January 1943.

Drilling depths		Thickness
Feet	*Oldman and Foremost*	Feet
10–140	Chiefly dark grey shale; some fine sandstone	130
140–160	Shale, grey; grey sandstone; lignite; little brown siltstone	20
160–190	Shale, grey; lignite	30
190–216	Shale, grey; little grey sandstone	26
216–225	Lignite; grey shale	9
225–236	Shale, grey; brown siltstone	11
236–254	Sandstone, grey; grey shale; brown siltstone	18
254–275	Shale, brown and black, organic, fissile; lignite; little sandstone	21
275–287	Sandstone, grey; grey shale; lignite	12
287–294	Siltstone, brown; fine grey sandstone	7
294–317	Shale, brown, organic, fissile; brown siltstone	23
317–406	Sandstone, grey; grey to black shale; brown siltstone	89
406–425	Shale, grey, sandy	19
425–455	Sandstone, grey	30
455–477	Shale, grey; black organic particles	22
477–524	Sandstone, grey, fine; little glauconite	47
524–534	Shale, grey	10
534–575	Sandstone, grey; little glauconite	41
575–585	Missing	10
585–595	Sandstone, grey; little glauconite	10
595–605	Sandstone, grey, fine; glauconite; brown glauconite-bearing siltstone	10
605–616	Lignite; brown and black, carbonaceous shale; little grey and brown siltstone and grey sandstone	11
616–666	Sandstone, grey, with little glauconite; little grey siltstone and glauconite-bearing brown siltstone; little lignite	50
666–675	Shale, brownish grey; black organic particles; little grey sandstone	9
675–685	Shale, grey; sandstone, grey; little lignite	10
685–695	Shale, grey; foraminifera (R.T.D. Wickenden)	10
695–705	Shale, grey; grey sandstone; little glauconite	10
705–725	Shale, grey; considerable lignite; little grey sandstone	20

Twin Province No. 1 Well—Continued

Drilling depths		Thickness
Feet		Feet
	Lea Park (Pakowki equivalent)	
725–800	Shale, medium grey, sandy at places; foraminifera (R.T.D. Wickenden)......	75
800–1,285	Shale, medium grey, sandy at places..	485
	Lea Park (Milk River equivalent)	
1,285–1,335	Shale, grey, with much brown siltstone; many tiny rounded chert pebbles; little sandstone; glauconite common in siltstone..........................	50
1,335–1,495	Shale, grey, with much brown siltstone with some glauconite; few chert pebbles to 1,395..	160
1,495–1,555	Shale, grey; grey sandstone with some glauconite; glauconitic brown siltstone	60
1,555–1,585	Shale, grey; grey sandstone; brown siltstone with a little glauconite; *Inoceramus* prisms..	30
	Alberta Formation	
1,585–1,765	Shale, grey, with white calcareous specks (first or upper speckled zone); *Inoceramus* prisms..	180
1,765–1,800	Shale, grey, fairly hard..	35
1,800–1,810	Shale, grey; *Inoceramus* prisms.......................................	10
1,810–1,910	Shale, medium grey...	100
1,910–2,040	Shale, medium grey, contains speckled shale, shale quite calcareous; numerous *Inoceramus* prisms..	130
2,040–2,050	Shale, dark grey, slickensided......................................	10
2,050–2,070	Shale, speckled, dark grey..	20
2,070–2,080	Shale, dark grey..	10
2,080–2,100	Shale, dark grey, speckled..	20
2,100–2,105	Missing..	5
2,105–2,165	Shale, dark grey; large amount of pyrite..............................	60
2,165–2,265	Shale, dark grey; with pyrite..	100
2,265–2,560	Shale, dark grey..	295
2,560–2,570	Shale, dark grey, calcareous (top of lower or second speckled zone ?).........	10
2,570–2,700	Samples missing..	130
2,700–2,710	Shale, dark grey, some sand..	10
	Lower Cretaceous or (?) Alberta Formation ("Blackleaf" member)	
2,710–2,720	Chert pebbles up to 6 to 8 mm.; some fine-grained white sand; probably top of Lower Cretaceous..	
2,720–2,760	Shale, dark grey; much fine white sand and chert pebbles.................	
2,760–2,770	Shale, dark brownish grey; some fine-grained sand; some fragments of carbonized plants..	
2,770–2,780	Sands, grey, pepper and salt, fine-grained; a little bentonite..............	
2,780–2,800	Shale and sand, grey; bentonite.......................................	
2,800–2,810	Sand, pepper and salt, fine-grained; a little glauconite....................	
2,810–2,850	Shale and sand, grey; numerous fragments of buff concretions...............	
	Lower Cretaceous: chiefly marine	
2,850–3,100	Shale, dark grey; few foraminifera; bentonite at 2,860 to 2,880; *Inoceramus* prisms common 3,030 to 3,080; sandy, with much pyrite from 3,080 to 3,100	
3,100–3,110	Shale, dark grey, sandy; few chert pebbles.............................	
3,110–3,120	Shale, sandy, grey; many chert pebbles.................................	
3,120–3,125	Sand, grey, much pyrite..	
3,125–3,130	Shale, medium to light grey; a little sand with many green grains...........	
3,130–3,150	Sand, medium grey...	
3,150–3,170	Shale, sandy, medium to dark grey; some of the shale looks sheared........	
3,170–3,180	Shale, medium grey; a little sand; many buff granules......................	
	Lower Cretaceous: chiefly non-marine	
3,180–3,200	Shale, purplish red; a little sand....................................	
3,200–3,210	Shale, greenish grey...	
3,210–3,220	Shale, medium grey...	
3,220–3,240	Sand, grey, fine-grained..	
3,240–3,248	Shale, greenish grey...	
3,248–3,251	Sandstone granules, buff cement......................................	
3,251–3,290	Sand, grey to buff, fine-grained......................................	

Twin Province No. 1 Well—Concluded

Drilling depths		Thickness
Feet	*Jurassic*	Feet
3,290–3,310	Shale, brownish grey	
3,310–3,350	Shale, light grey and brownish grey; many fragments of drill bit; a few foraminifera; Jurassic species at 3,350	
3,350–3,370	Shale, medium to light grey	
3,370–3,477	Sandstone and shale, medium to light grey	
3,477–3,480	Sandstone, grey; a little medium grey shale; many fragments of fossil shells; some foraminifera and ostracods	
3,480–3,490	Shale and sandstone, grey; many fragments of fossil shells, some foraminifera and ostracods	
3,490–3,504	Limestone, cream coloured, with some dark grey inclusions, somewhat chalky texture; a few ostracods	
3,504–3,510	Limestone, light cream to white, more chalky texture than above; few dark grey inclusions; some rounded particles look like oolites	
3,510–3,524	Limestone, white, chalky; a few fossil fragments	
3,524–3,531	Limestone, cream to light buff, chalky; some grey shale and sandstone	
3,531–3,547	Limestone, light buff; some finely granular dark buff to brown limestone; some medium grey shale	
3,547–3,560	Limestone; light buff and medium grey shale; much fine-grained grey sand. Sand may have fallen from higher beds when casing was pulled back	
3,560–3,570	Limestone, light buff to cream, rather dense and amorphous; some medium grey shale	
3,570–3,580	Limestone, light buff to cream; a little shale; limestone is dense rather amorphous, a few quartz crystals and clear grains	
3,580–3,585	Mostly limestone, but many steel chips have covered material with rust	
3,585–3,595	Shale, medium grey, fairly hard; very little limestone and few grains of sand; some pyrite—Jurassic foraminifera	
3,595–3,610	Shale, medium grey; some grey fine-grained calcareous sandstone; much pyrite; Jurassic foraminifera and ostracods	
3,610–3,615	Shale, medium grey; much light grey and some medium grey sandstone, with pyrite; fewer foraminifera than above; ostracods about the same	
3,615–3,620	Shale, medium grey; some fine-grained grey sandstone; much pyrite; few ostracods; very few foraminifera	
3,620–3,635	Shale, medium grey; some buff limestone with dark streaks; a little fine-grained grey sandstone; some pyrite	
3,635–3,649	Mixture of cream-coloured limestone, grey shale, and brown limestone; a little light grey shale and a few fragments of chalcedony	
3,649–3,655	Shale, medium grey; much fine-grained sandstone. A little chalcedony and cream limestone; very few ostracods	
3,655–3,665	Shale, medium grey; some grey sandstone and chalcedony	
3,665–3,670	Limestone, cream coloured, and medium grey shale	
3,670–3,677	Limestone, cream, and shale, medium grey; many fragments of pale green shale; some grit with a pale green or white matrix; many fragments of chalcedony and some calcite; a few grains of grey chert	

NOTE. Well continued to depth of 3,970 feet (October 1945) but samples not examined.

Signal Butte No. 1 Well[1]

Operators: A. B. Cobb and Co., and Yale Oil Corp.

Location: SE. ¼, NE. ¼ sec. 19, tp. 37N, rge. 15E, Montana, 326 feet N. of S. line, 617 feet E. of W. line.

Elevation: 2,915 feet. Drilling April 20, 1941, to Nov. 19, 1941. Log by G. L. Postle[2].

Drilling method: Rotary.

Drilling depths		Thickness
Feet		Feet
	Oldman and Foremost	
0–40	Clay and sandstone	40
40–80	Sandstone	40
80–194	Sandstone (water)	114
194–500	Shale and sandy shale	306
500–742	Shale, dark red and yellow specks	242
742–892	Shale, sandy	150
892–1,080	Shale, dark	188
1,080–1,160	Shale, dark sandy	80
1,160–1,190	Sandstone	30
	Lea Park (?)	
1,190–1,198	Shale	8
1,198–1,230	Shale, dark sandy	32
1,230–1,285	Shale, dark	55
1,285–1,302	Shale, black	17
1,302–1,377	Shale, dark, and yellow bentonite	75
1,377–1,384	Shale	7
1,384–1,390	Sandstone	6
1,390–1,500	Shale and bentonite	110
1,500–1,770	Shale, soft black	270
1,770–1,830	Shale, dark grey silty	60
	Equivalent of Alberta Formation (?)	
1,830–1,870	Shale, soft black	40
1,870–1,890	Shale, soft black; some silty shale	20
1,890–2,000	Shale, soft black	110
2,000–2,080	Shale, soft black; some silty shale	80
2,080–2,100	Shale, dark grey silty and soft black shale	20
2,100–2,120	Shale, soft black; some silty shale; pyrite	20
2,120–2,150	Shale, dark grey silty and soft black shale	30
2,150–2,260	Shale, soft black; pyrite	110
2,260–2,280	Sandstone, very fine-grained grey; fair rounding, poor sorting	20
2,280–2,390	Shale, soft black, some silty shale; calcite; shell particles	110
2,390–2,400	Shale, silty and soft black shale	10
2,400–2,480	Shale, soft dark grey	80
2,480–2,500	Sandstone, fine-grained dark grey, fair rounding, poor sorting	20
2,500–2,510	Shale, dark grey	10
2,510–2,520	Bentonite	10
2,520–2,560	Shale, dark grey	40
2,560–2,580	Shale, sandy, dark grey	20
2,580–2,690	Shale, dark grey	110
2,690–2,700	Bentonite	10
2,700–2,730	Shale and bentonite	30
2,730–2,765	Shale, dark grey, sandy	35
2,765–2,895	Shale, dark grey	130
2,895–2,900	Sandstone, dark grey	5
2,900–2,955	Shale, dark grey	55
2,955–2,970	Shale, sandy, dark grey	15
2,970–3,030	Shale, dark grey	60
3,030–3,032	Sandstone, hard, grey, calcareous	2
3,032–3,033	Sandstone, soft, grey, porous, calcareous	1
3,033–3,038	Bentonite	5
3,038–3,048	Shale, black, brittle	10
3,048–3,090	Shale, black and grey; bentonite streaks 3,070 to 3,075	42
3,090–3,101	Sandstone, hard, grey	11
3,101–3,121	Sandstone, dark grey	20

[1] Mr. Postle's log of the Signal Butte No. 1 well is presented here by courtesy of A. B. Cobb and Company, and the Yale Oil Corporation, Cutbank, Montana.

[2] Geologist for A. B. Cobb and Company and the Yale Oil Corporation, Cutbank, Montana.

Signal Butte No. 1 Well—Continued

Drilling depths		Thickness
Feet		Feet
	Colorado (Alberta) Formation or Lower Cretaceous (?)	
3,121–3,123	Bentonite	2
3,123–3,138	Shale, black, with thin breaks of grey sandstone	15
3,138–3,170	Shale, dark grey	32
3,170–3,185	Shale, sandy, dark grey	15
3,185–3,188	Sandstone, fine-grained, dark grey	3
3,188–3,190	Sandstone, fine-grained, green	2
3,190–3,192	Sandstone, fine-grained, green, with thin shale breaks. Trace of gas	2
3,192–3,194	Sandstone, fine-grained, green	2
3,194–3,230	Shale, sandy, dark grey, and interbedded fine-grained grey sandstone and dark grey shale. Sandstone is clayey with fair rounding, fair sorting and low porosity. Small show of gas	36
	Lower Cretaceous: probably marine	
3,230–3,233	Bentonite	3
3,233–3,260	Shale, dark grey. Streaks of bentonite 3,240 to 3,250	27
3,260–3,300	Shale, dark grey, and soft brownish grey shale	40
3,300–3,310	Bentonite	10
3,310–3,330	Shale, dark grey	20
3,330–3,335	Bentonite	15
3,335–3,370	Shale, dark grey	35
3,370–3,380	Bentonite	10
3,380–3,395	Shale, dark grey	15
3,395–3,405	Bentonite	10
3,405–3,465	Shale, dark grey	60
3,465–3,491	Shale, black	26
3,491–3,492	Interbedded black shale and hard grey sandstone	1
3,492–3,493	Bentonite	1
3,493–3,536	Shale, black	43
	Lower Cretaceous: non-marine	
3,536–3,540	Shale, soft green and grey	4
3,540–3,546	Shale, sandy, soft green	6
3,546–3,550	Shale, green	4
3,550–3,556	Shale, chocolate-brown	6
3,556–3,560	Sandstone, green clayey	4
3,560–3,566	Shale, soft green	6
3,566–3,574	Shale, soft brown	8
3,574–3,582	Shale, soft green, and sandstone	8
3,582–3,587	Shale, maroon and chocolate	5
3,587–3,588	Shale, purple and green	1
3,588–3,590	Shale, green and red	2
3,590–3,592	Sandstone, green	2
3,592–3,615	Sandstone, green shale	23
3,615–3,622	Shale, dark green	7
3,622–3,626	Shale, dark grey	4
3,626–3,642	Shale, maroon	16
3,642–3,646	Shale, purplish grey	4
3,646–3,646·5	Shale, grey and yellow	0·5
3,646·5–3,653	Shale, maroon	6·5
3,653–3,662	Shale, green	9
3,662–3,667	Sandstone, shaly, grey	5
3,667–3,670	Shale, green, sandy	3
3,670–3,680	Sandstone, fine-grained, grey, clayey, crossbedded	10
3,680–3,685	Sandstone, fine-grained, grey, with shale partings	5
3,685–3,691	Sandstone, fine-grained, grey, soft	6
3,691–3,709	Shale, green	18
3,709–3,711	Sandstone, green	2
3,711–3,717	Shale, greenish grey	6
3,717–3,720	Shale, red, brittle	3
3,720–3,724	Shale, grey	4
3,724–3,734	Shale, green	10
3,734–3,737	Sandstone, green	3
3,737–3,739	Sandstone, greenish grey, with shale partings	2
3,739–3,742	Sandstone, grey, calcareous; 0·2 feet pyrite; bituminous matter and grey shale at 3,741	3

Signal Butte No. 1 Well—Continued

Drilling depths		Thickness
Feet		Feet
	Lower Cretaceous: non-marine—*concluded*	
3,742–3,746	Shale, dark green	4
3,746–3,748	Sandstone, very soft, greenish grey, clayey	2
3,748–3,750	Sandstone, hard, calcareous, crossbedded	2
3,750–3,758	Sandstone, soft, grey, slightly calcareous. Water 3,734 to 3,758	8
3,758–3,760	Shale, hard grey, with sand lenses	2
	Jurassic	
3,760–3,786	Interbedded soft to firm, light grey sandstone and dark grey shale. Sandstone is very fine grained, well rounded, and well sorted. Slight show of gas	26
3,786–3,795	Sandstone, very soft, buff, micaceous, very fine grained, well sorted and well rounded	9
3,795–3,835	Interbedded firm dark grey shale and grey sandy shale	40
3,835–3,840	Shale, dark grey; trace of limestone	5
3,840–3,890	Dark grey shale and thin sandy streaks	50
3,890–3,905	Shale, dark grey	15
3,905–3,932	Shale, dark grey, with streaks of calcareous shale	27
3,932–4,055	Shale, calcareous, firm, dark grey. Fossil beds (*Gryphaea* and *Belemnites*) at 3,937 to 3,940 and 3,969	123
4,055–4,056	Limestone, hard, dark grey	1
4,056–4,066	Shale, calcareous, firm, dark grey. Fossiliferous from 4,065 to 4,066	10
4,066–4,067	Limestone, hard, dark grey, fossiliferous	1
4,067–4,071	Shale, calcareous, firm, dark grey	4
4,071–4,072	Limestone, hard, dark grey	1
4,072–4,073	Shale, firm, dark grey, calcareous	1
4,073–4,074	Limestone, hard, dark grey	1
4,074–4,086	Shale, firm, dark grey, calcareous	12
4,086–4,089	Limestone, fossiliferous	3
4,089–4,106	Sandstone, very fine-grained, tight, calcareous, with thin white dolomitic limestone breaks. Light saturation with dark oil. Small show of gas. Water	17
4,106–4,111	Sandstone, very fine-grained, calcareous; good sorting, fair rounding. Slight saturation	5
4,111–4,112	Limestone, hard, sandy	1
4,112–4,118	Sandstone, fine-grained, calcareous, honeycombed with pin-sized holes. Very slight saturation	6
4,118–4,124	Sandstone, calcareous, very fine-grained, tight. Good sorting, fair rounding. Light saturation. Show of gas	6
4,124–4,125	Limestone, dark grey, sandy	1
4,125–4,130	Sandstone, calcareous, very fine-grained, dark grey, with streaks and small inclusions of white dolomitic limestone. Good rounding and fair sorting. Slight saturation	5
4,130–4,132	Sandstone, calcareous, soft, very fine-grained. Good rounding, fair sorting. Light saturation	2
4,132–4,135	Sandstone, hard; dark grey and grey, sandy limestone	3
4,135–4,135·5	Limestone, dark grey, sandy	0·5
4,135·5–4,136	Shale, dark grey	0·5
4,136–4,137	Limestone, dark grey, sandy	1
4,137–4,137·2	Shale, dark grey	0·2
4,137·2–4,137·5	Shale, dark grey, sandy	0·3
4,137·5–4,144	Sandstone, calcareous, soft, light grey, very fine-grained, with calcareous oolites. Excellent rounding, good sorting. Light saturation	6·5
4,144–4,146	Sandstone, calcareous, soft, light grey, very fine-grained, with fragments of buff limestone and chert at the bottom	2
4,146–4,179	Limestone, massive, buff; some chert. Black coating on some particles	33
4,179–4,199	Limestone, dolomitic, putty coloured. Vertical fractures filled with knife blade calcite seams	20
4,199–4,206	Limestone, fossiliferous; grey. Show of oil at 4,200	7
4,206–4,224	Limestone, shaly, fossiliferous, dark grey, and buff and grey fossiliferous limestone	18
4,224–4,240	Shale, calcareous, dark grey	16
4,240–4,246	Shale, dark grey, slightly calcareous	6
4,246–4,247	Shale, black	1
4,247–4,248	Shale, dark grey, slightly calcareous	1
4,248–4,250	Limestone, grey, shaly	2
4,250–4,260	Shale, dark grey	10
4,260–4,267	Shale, slightly calcareous, hard, grey, slightly sandy	7

Signal Butte No. 1 Well—Concluded

Drilling depths		Thickness
Feet		Feet
	Madison (?)	
4,267–4,280	Conglomerate, bluish green, shale matrix with small fragments of limestone and larger fragments of chert. Considerable pyrite. Sulphur odour. Top of Madison determined by Great Falls Office	13
4,280–4,303	Limestone, dolomitic, and grey chert	23
4,303–4,323	Limestone, light grey. Pinhead sized spots of oil in cracks at 4,317 and 4,321	20
4,323–4,326	Limestone, shaly, maroon	3
4,326–4,341	Limestone, shaly, maroon, and white limestone in bands irregularly spaced and of irregular thickness	15

Oil or gas sands....4,106–4,132; 4,138–4,146
Water sands....80–194; 4,089–4,186
Coring record....4,030–4,048; 3,101–3,138; 3,188–3,235; 3,465–3,566; 3,574–3,812; 3,880–4,001
4,001–4,019; 4,050–4,285; 4,305–4,341
Formation tests by Haliburton Drill Stem Method:
No. 1. 3,732–3,760—15 mins.—120 ft. water, 45 lbs. B.H.P.
No. 2. 4,078–4,106—27 mins.—650 ft. water, scum of oil, 42 lbs. B.H.P.
No. 3. 4,107–4,135—30 mins.—45 ft. mud, scum of oil, 0 lbs. B.H.P.
No. 4. 4,132–4,146—19 mins.—12 ft. mud, scum of oil, 0 lbs. B.H.P.

Gem Dome Oil and Gas No. 1 Well

Location: l.s. 6, sec. 4, tp. 10, rge. 29, W. 3rd mer.
Elevation: derrick floor, 3,048 feet.
Standard rig: total depth, 302 feet.
Abandoned at 302 feet.

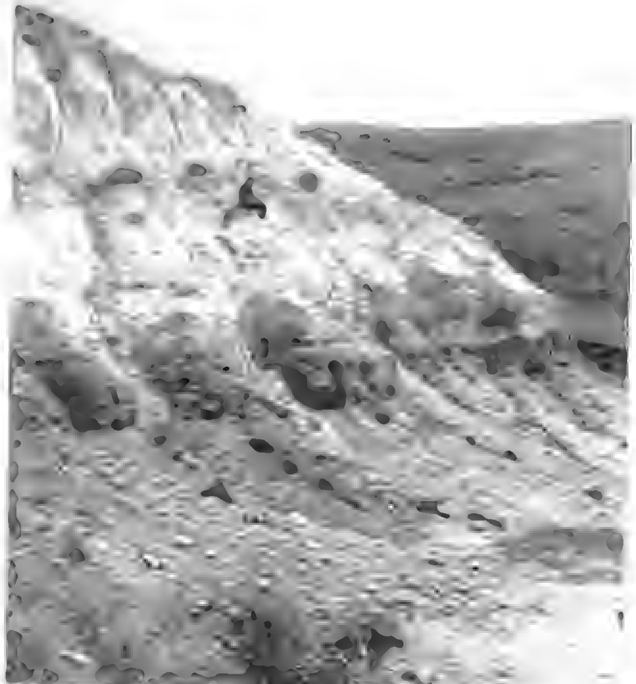
Drilling depths		Thickness
Feet		Feet
	Bearpaw	
0–230	Chiefly dark grey shale	230
230–250	Shale, dark grey; little brown siltstone and greenish grey indurated sandstone	20
250–270	Shale, dark grey; little fine sand; rounded glassy quartz grains	10
270–280	Shale, dark grey; one large fragment hard, fine-grained, greenish grey sandstone; brown siltstone	10
280–290	Shale, dark grey; brown siltstone	10
290–302	Sandstone, greenish grey, hard, calcareous, contains glauconite; several fragments of ammonites or *Baculites* sp.; appears to be definitely a marine sandstone and to belong to concretionary sandstone bed 120 feet above Bearpaw-Oldman contact, rather than to Oldman sandstone	10

PLATE II

88736

A. Belanger sandstone member (with concretions) in Bearpaw shale. Cut bank east side of Battle Creek, below Fort Walsh, NE. ¼ sec. 9, tp. 7, rge. 29, W. 3rd mer.

B. Oxarart sandstone member of Bearpaw east side of Thelma Creek, SE. ¼ sec. 1, tp. 7, rge. 3, W. 3rd mer.



87158

A. The No. 2 carbonaceous zone and overlying No. 3 white clay zone of the Whitemud formation. South side of Frenchman River east of Ravenscrag in NE. ¼ sec. 15, tp. 6, rge. 23, W. 3rd mer.

87161

B. Coarsely crossbedded Frenchman sandstone lying unconformably upon the Whitemud formation (No. 3 zone). South side of Frenchman River east of Ravenscrag in NE. ¼ sec. 20, tp. 6, rge. 23, W. 3rd mer.

A. General view looking northeast across valley of Battle Creek below Fort Walsh. Frenchman formation in foreground, NE. ¼ sec. 8, tp. 7, rge. 28, W. 3rd mer

88742

B. Cypress Hills conglomerate, west side Adams Lake, SE. ¼ sec. 15, tp. 8, rge. 29, W. 3rd mer.

INDEX

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LEGEND

CENOZOIC

TERTIARY
OLIGOCENE

9 — *CYPRESS HILLS FORMATION: conglomerate and sandstone*

PALEOCENE

8 — *RAVENSCRAG FORMATION: sand, silt, shale; lignite*

MESOZOIC

CRETACEOUS
UPPER CRETACEOUS

7 — *FRENCHMAN FORMATION: mainly coarse sandstone*
BATTLE FORMATION: black and green bentonite, shale, silt

6 — *WHITEMUD FORMATION: white kaolinized sandstone, light coloured clay and silt; lignite*

5 — *EASTEND FORMATION: buff to brown silt and fine sand; grey shale; lignite*

4 — *BEARPAW FORMATION: dark marine shale, sandstone, bentonite; concretionary beds*

3 — *OLDMAN FORMATION: sandstone, shale; lignite*

2 — *OLDMAN AND FOREMOST FORMATIONS: sandstone, shale; lignite*

1 — *LEA PARK FORMATION: dark marine shale with concretionary layers and bentonite beds*

Outcrops of Belanger member of Bearpaw formation
Outcrops of Oxarart member of Bearpaw formation
Outcrops (bedding horizontal, inclined)
Fault
Well (dry hole)

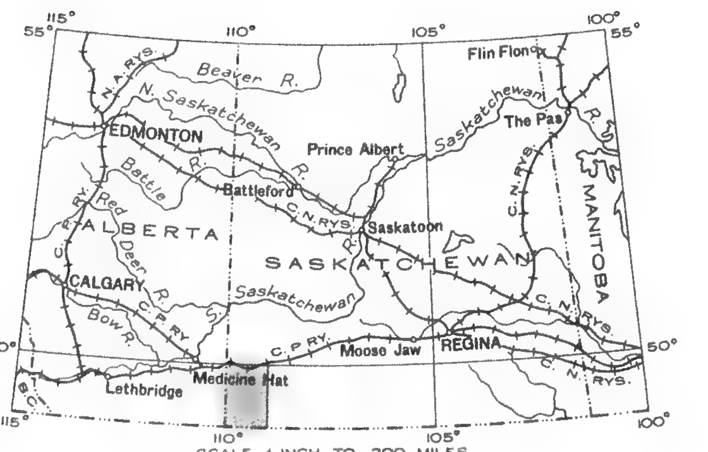
Post Office
Railway Station and Post Office
International boundary
Township boundary
Forest Reserve boundary
Park and Indian Reserve boundary
Section line
Irrigation canal
Intermittent lake and stream
Stream (position approximate)
Marsh
Contours (interval 100 feet) 3000
Contours (position approximate) 3000
Depression contour
Height in feet above Mean sea-level 3070′

Geology by G.M. Furnival, 1940, 1941.

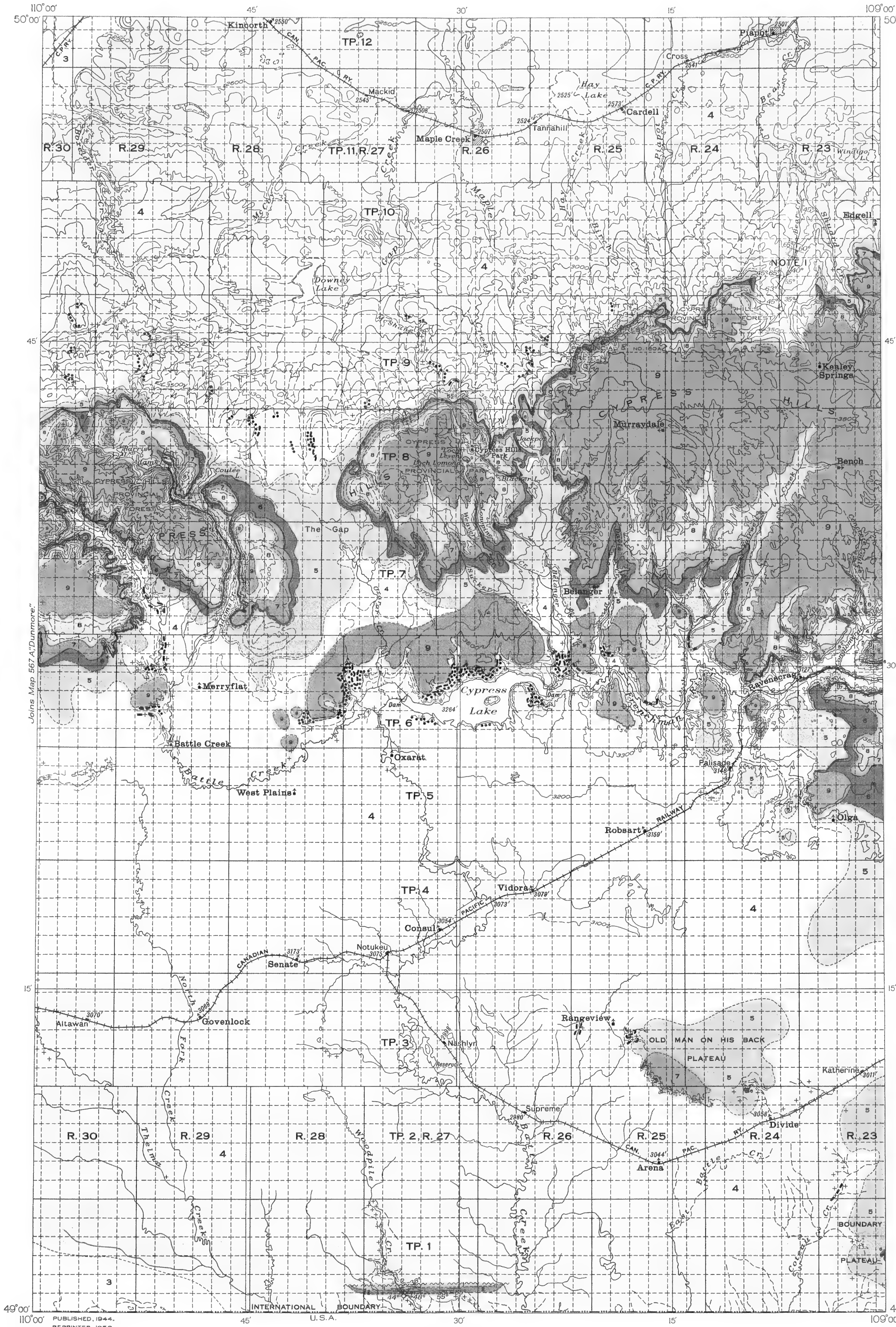
Base-map compiled by the Topographical Survey, 1943, from information supplied by Federal Government Departments and by the Government of the Province of Saskatchewan, with additions by the Geological Survey. Cartography by the Drafting and Reproducing Division, 1944.

DIAGRAM OF TOWNSHIP
SHOWING NUMBERING OF SECTIONS

31	32	33	34	35	36
30	29	28	27	26	25
19	20	21	22	23	24
18	17	16	15	14	13
7	8	9	10	11	12
6	5	4	3	2	1



SCALE, 1 INCH TO 200 MILES



PUBLISHED, 1944.
REPRINTED, 1950.

MAP 784A

CYPRESS LAKE

WEST OF THIRD MERIDIAN
SASKATCHEWAN

Scale, $\frac{1}{253,440}$ or 1 Inch to 4 Miles
Miles
4 0 4 8 12

Approximate magnetic declination, 20° East.

DESCRIPTIVE NOTES

The oldest exposed rocks are dark grey shales, sandy shales and minor amounts of shaly sand of the Lea Park formation (1). These include the equivalents of the Pakowki, Milk River, and part of the Foremost formations of southern Alberta. Glauconite is common in the sandy beds and the formation appears to be largely of marine origin. Contacts with other formations are not exposed but well borings within the map-area indicate a thickness of 750 feet.

Beds of the Oldman and Foremost formations of southern Alberta are exposed in two limited areas. In the faulted section along Woodpile Creek parts of both formations (2) are incompletely exposed and cannot be differentiated. Only the upper few feet of the Oldman formation (3) is exposed in the northwest corner of the map-area. Massive, thick sandstones appear fairly abundant in the lower part of the Woodpile Creek section; shales and organic beds are numerous in the upper portion. Lignite seams, some of which have been mined, are common in the upper 160 feet. Both marine and brackish water fossils are present. The Boundary well, at Woodpile Creek, commenced in and penetrated 980 feet of upturned and faulted beds of Oldman and Foremost age. The Twin Provinces No. 1 well, at the northwest corner of the map-area, penetrated a section representing a true, combined thickness of 695 feet of these beds. Glauconite is common in the sands of the lower 360 feet. Interbedded with these are beds of organic shale, lignite, and dark grey shale. This part of the section represents a transition to the underlying marine-shales of the Lea Park.

The Bearpaw formation (4) underlies much of the map-area but at no place is a complete section exposed nor do any wells penetrate the entire formation. From a composite section measured along Boxelder Creek it is estimated that the Bearpaw is 930 feet thick. It consists mainly of dark marine shale but contains occasional sandstone and sandy strata. Two sandstone members, the Oxarart and the Belanger, have proved to be valuable horizon markers and were used to investigate the structure of this part of the Cypress Hills. The Oxarart is composed of fairly massive, grey to buff sandstone that, at the top, is hard, rusty, and greenish-grey and contains much white fossilized wood, plant impressions, worm burrowings, etc. In it, at places, are seams of lignite, as much as 2.5 feet thick, and occasional oyster beds. The Oxarart thickens from more than 20 feet on Davis Creek to 65 feet one mile west of Oxarart Creek, and to 90 feet on Boxelder Creek. The top appears to be everywhere 190 to 200 feet below the Bearpaw-Eastend contact. The Belanger member lies 25 feet above the Oxarart and is uniformly 20 to 25 feet thick. It consists of brown and grey sandstone and dark shale, and contains a calcareous concretionary layer, rich in fossils, that commonly outcrops as a prominent ledge, in general 35 to 40 feet above the hard ledge-forming surface of the Oxarart member.

The Eastend formation (5) consists mainly of buff to brown and grey very fine sands, with some silts and grey shale. Organic laminae are numerous and to the west lignite seams are present. Contacts are transitional into the underlying marine Bearpaw and the overlying non-marine Whitemud formations. The Eastend is consequently considered to represent a transition from marine to non-marine conditions of sedimentation. It ranges in thickness from 65 feet to 100 feet.

The Whitemud formation (6) is from 50 to 75 feet thick. The name is here restricted to the mainly refractory, light coloured and white, kaolinized feldspathic sandstone, silt, and clay beds that comprise zones 1, 2, and 3 of the formation as described from the type sections at Whitemud, Saskatchewan. The formation has originated under conditions of alluvial or subaerial deposition.

The Battle formation (7, in part), where present, is as much as 30 feet thick. The name is here given for the first time and applies to strata that occur at places between the Whitemud and the Frenchman formations. It includes the black bentonitic shale, formerly referred to the No. 4 zone of the Whitemud, and olive green bentonite, shale, and silt lying above the black bentonitic shale.

The Frenchman formation (7, in part) ranges in thickness from 25 feet to 225 feet. The name is here applied for the first time to the beds that lie above an erosional unconformity within what was formerly called the Lower Ravenscrag. The formation consists mainly of coarse, cross-bedded and massive, compacted to indurated brown and greenish brown sandstone, with minor amounts of green and grey shale, silt, bentonitic shale, and bentonite. It is of non-marine origin. Dinosaur remains have been collected from it at widely scattered points.

The Ravenscrag formation (8) is 250 to 280 feet thick. The name is here used to apply only to strata that previously comprised the Upper Ravenscrag. They are conformable with underlying Frenchman beds. The formation is of non-marine origin and consists of buff and grey fine sands, silts, and shales, with numerous lignitic seams. It is divisible into an upper buff facies and a lower grey facies.

The Cypress Hills formation (9) lies unconformably above the Ravenscrag and all older formations down to and including the Bearpaw. It consists of thick beds of coarse conglomerate and massive cross-bedded hard grey coarse sandstone, generally underlying the plateau-like surface of the Cypress Hills.

The strata exposed in the Cypress Hills drop in elevation at an average rate of 13 feet per mile eastward, in the distance between the east and west boundaries of the map-area. North of the hills the regional dip is northeastward. The apparent northward dip, measured in a north-south section, increases from 10 feet per mile, near the northern border of the map-area, to 50 feet per mile in the southern part of township 9. On the south slopes of Cypress Hills, outcrops of the Oxarart and Belanger members of the Bearpaw formation, as measured along five north-south vertical sections, are from 50 to over 100 feet lower than outcrops of the same members on the north slopes of the hills.

The top of the Whitemud formation at Boundary Plateau in sec. 15, tp. 1, rge. 23, is 213 feet below the same horizon on the north side of Frenchman River Valley in sec. 26, tp. 6, rge. 23. The base of the Whitemud at the west end of Old Man On His Back Plateau, is at an elevation of 3,450 feet. As the formation is here at least 55 feet thick, the elevation of its top would be 3,505 feet, as compared with 3,212 feet at Boundary Plateau. The difference in elevation between these two points represents an average drop of 16.5 feet per mile southeast.

The Belanger member outcrops at an elevation of 3,237 feet at the west end of Old Man On His Back Plateau, in sec. 15, tp. 3, rge. 25, as compared with 2,944 feet in Coteau Creek, in sec. 6, tp. 2, rge. 23. The difference represents an average fall of 21.7 feet per mile between these two points. What may be the Belanger member outcrops at an elevation of 3,142 feet in sec. 19, tp. 3, rge. 25. The average fall in elevation between there and sec. 15, tp. 3, rge. 25, is 35 feet per mile, suggesting a possible sharp reversal in dip or faulting.

The elevation of the contact of the Bearpaw and Oldman formations has been measured at the following localities:

Twin Province No. 1 well .... 2512 feet
Gem Dome Oil and Gas well (the contact is estimated to lie at 110 feet below the bottom of the well) .... 2638 feet
Well drilled for water by town of Senate, NE.¼, sec. 3, tp. 4, rge. 28 .... 2665 feet
Woodpile Creek, sec. 4, tp. 1, rge. 27 (on south or upthrown side of thrust fault) .... 2635-2650 feet

The cumulative evidence indicates that the general structure may be an easterly plunging, broad, gentle anticline.

NOTE 1. The strata within the uncoloured area dip at high angles and are slickensided (particularly bentonite beds), crumpled, and drag-folded to such an extent as to indicate deformation under pressures much greater than could be attributed to slumping. A northward-trending thrust fault probably lies immediately west of the outcrops indicated within this area.

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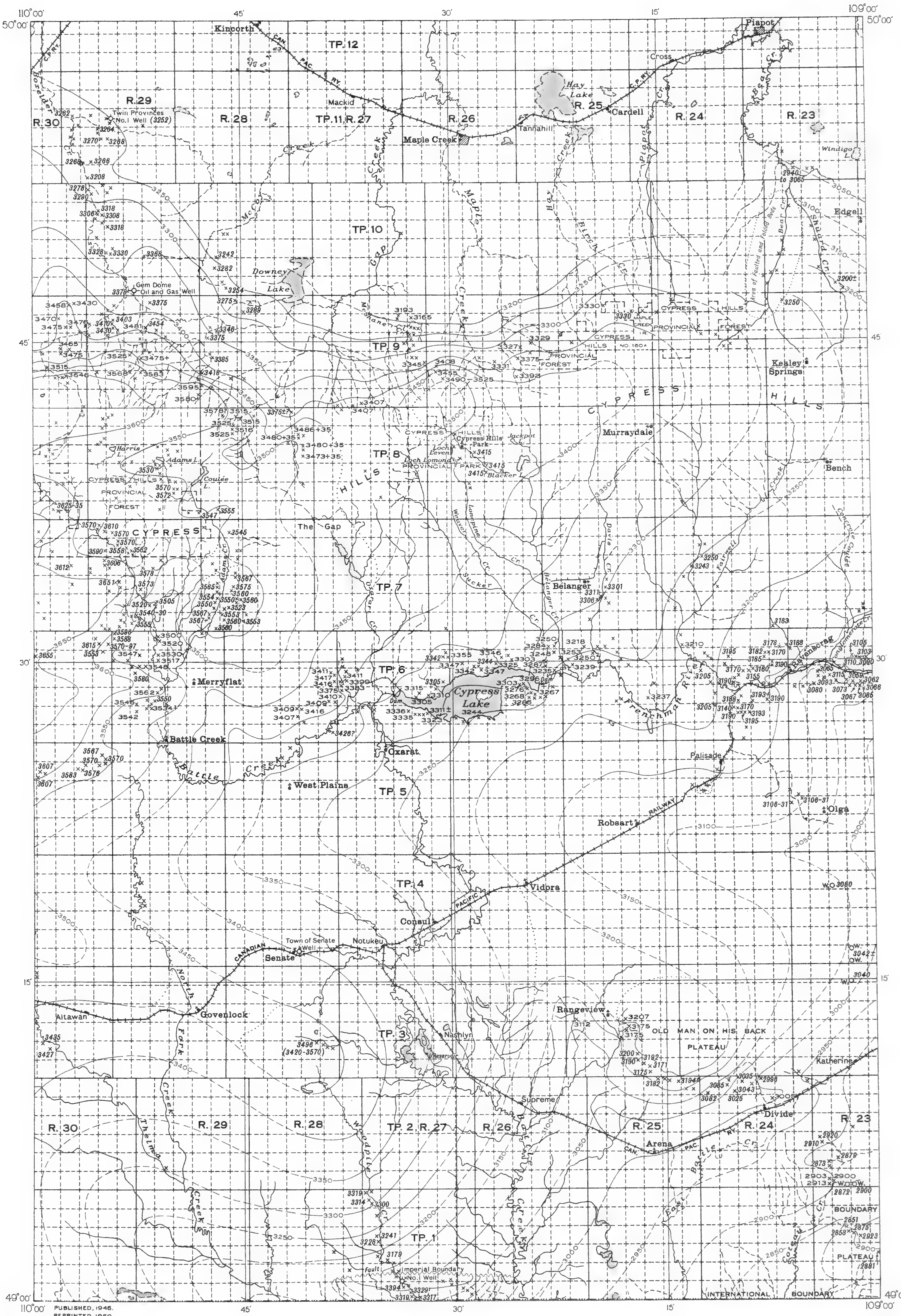
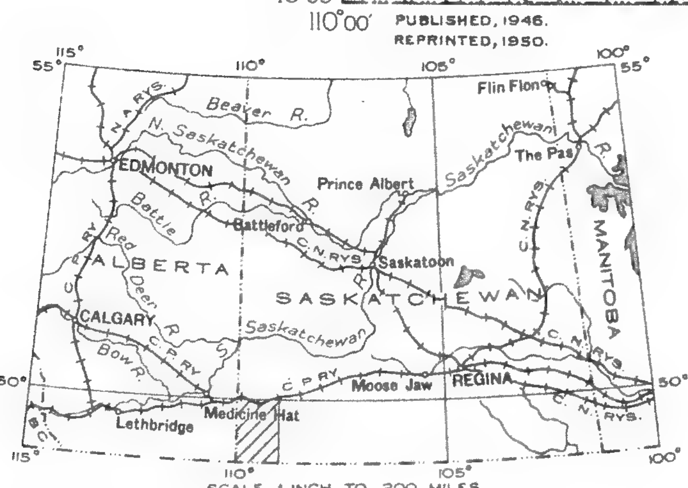


PUBLISHED, 1946.
REPRINTED, 1950.



MAP 856A

STRUCTURE-CONTOURS
CYPRESS LAKE
WEST OF THIRD MERIDIAN
SASKATCHEWAN

Scale, $\frac{1}{253,440}$ or 1 Inch to 4 Miles
Miles
4 0 4 8 12

Approximate magnetic declination, 20° East.

LEGEND

Structure-contours drawn on top of the Oxarart member of the Bearpaw formation (approximate; assumed; alternate assumed position)
Elevations determined on the top of the Oxarart member or calculated from the Belanger member of Bearpaw formation .... 2913 ×
Elevations of the Oxarart as determined by vertical intervals from other horizons .... 2923 ×
Outcrop stations .... ×
Oil well .... ✧
Water well .... W.O

Structure-contour interval 50 feet.

Structure-contours by G. M. Furnival, 1940, 1941.

Cartography by the Drafting and Reproducing Division, 1945.

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